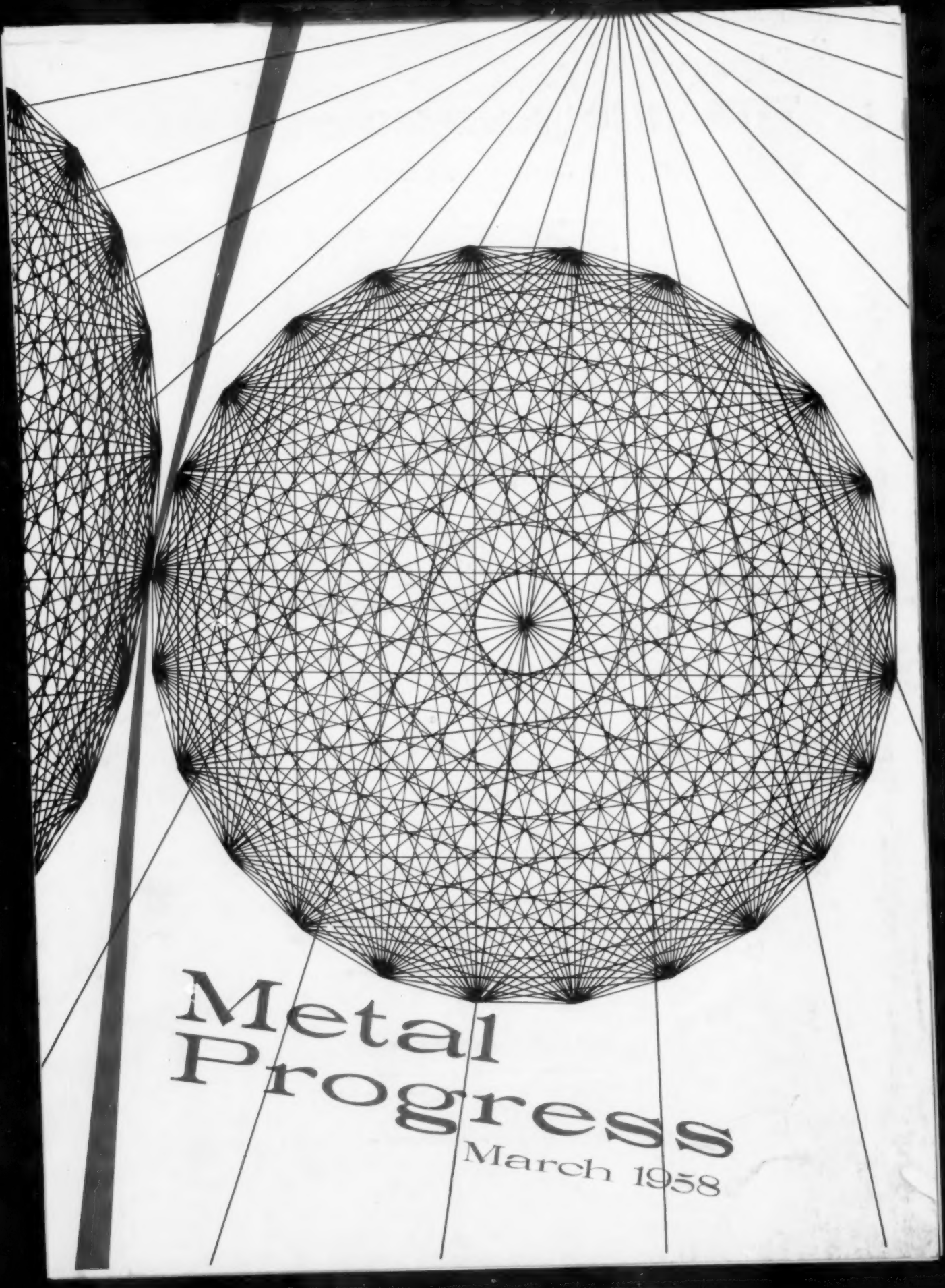
Metal
Progress
March 1958

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for your corrosion problem areas

TYPICAL CORROSION RESISTANCES OF ZIRCONIUM AND TITANIUM

CORROSIVE MEDIA	METAL RESISTANCE	
	ZIRCONIUM	TITANIUM
Sulfuric Acid	excellent to good below 80%	good below 5%
Nitric Acid	excellent	excellent
Hydrochloric Acid	excellent	good below 10%
Phosphoric Acid	excellent to fair below 85%	poor
Chromic Acid	excellent	excellent to good
Aqua Regia	poor	excellent
Wet Chlorine Gas	poor	excellent
Chlorine Water	excellent	excellent
Sodium Hydroxide	good below 90%	good below 50%
Ferric Chloride	poor	excellent
Calcium Chloride	excellent	excellent
Cupric Chloride	poor	excellent
Sodium Chloride	excellent	excellent
Ammonium Chloride	excellent	excellent
Aluminum Chloride	excellent	excellent to fair

Chart shows corrosion resistances of zirconium and titanium to typical chemicals.

Steam jet made of zirconium, which has given trouble-free performance after a year in hydrochloric acid service. For comparison, a throat piece from a steam jet (below) is shown after only a week of similar service.

By specifying titanium or zirconium for processing equipment, you can now overcome most of the corrosive media which attack other metals.

Even with such hard-to-handle chemicals as chlorides and oxidizing acids, equipment can have extremely long service life when made from these corrosion-resistant materials. Problems of product contamination in chemical and food processing can also be virtually eliminated.

Mallory-Sharon is in position to offer you *both* titanium and zirconium mill products for equipment fabrication—plus engineering assistance and unbiased recommendations on the most suitable material.

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For information on the corrosion-resistant properties of titanium or zirconium write Mallory-Sharon Metals Corporation, Niles, Ohio.

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Metal Progress

Volume 73, No. 3

March . . . 1958

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Descaling of Titanium, by W. B. Stephenson, Jr. 87
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METAL PROGRESS is published monthly by the AMERICAN SOCIETY FOR METALS. Publication office, Mt. Morris, Ill. Editorial, executive and advertising offices, 7301 Euclid Ave., Cleveland 3, Ohio. Subscription $7.50 a year in U.S. and Canada; foreign $10.50. Single copies $1.50; special issues $3.00 . . . The A.S.M. is not responsible for statements or opinions in this publication.

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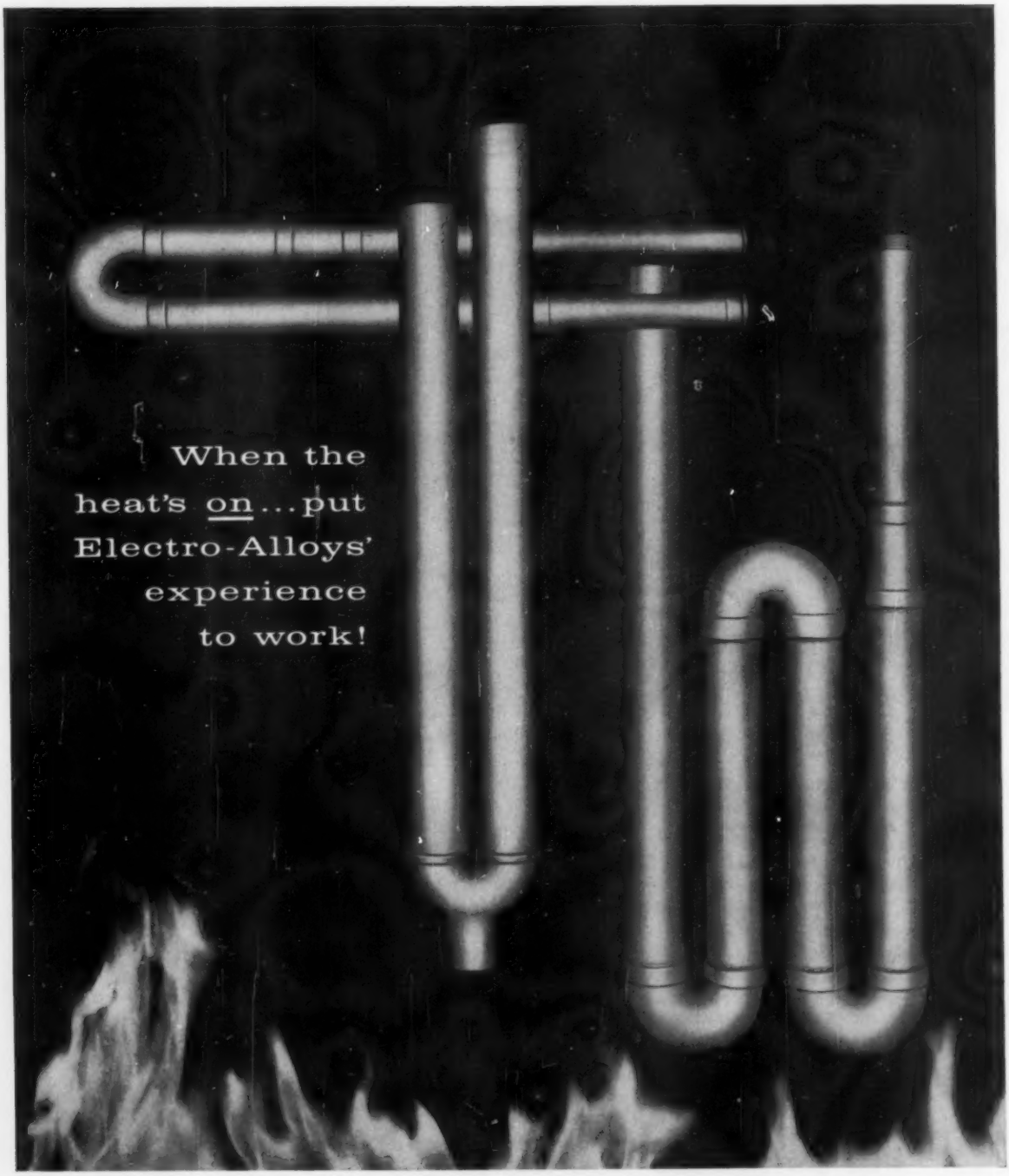

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What's Happened to Cermets? by J. W. Graham and W. F. Zimmerman 89
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A High-Strength Cast Steel, by C. G. Mickelson and R. D. Engquist 97
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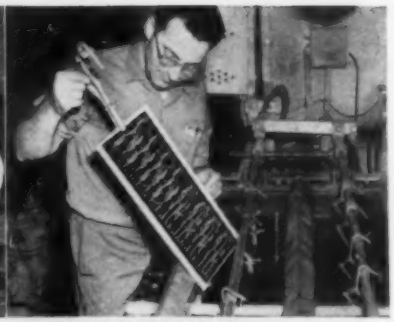
Plating Stereotypes



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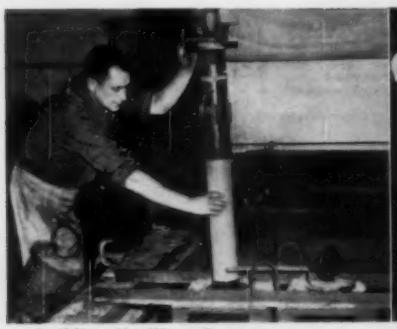

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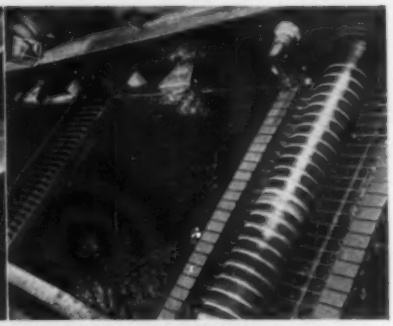

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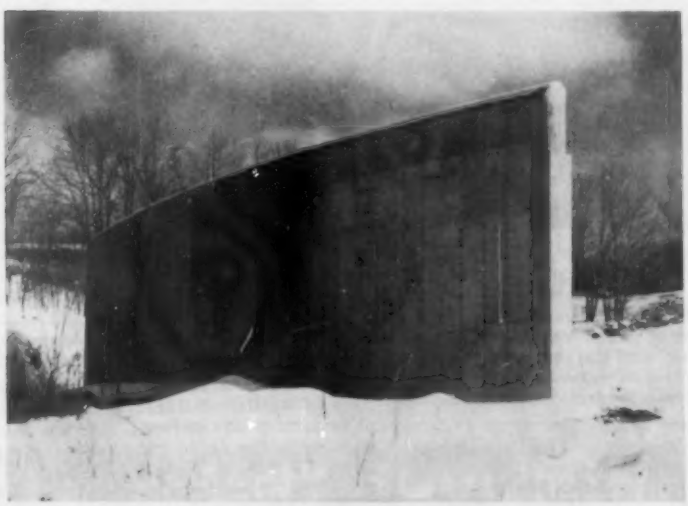
As I was saying...

It seems to me about time to present to you again the partners with A.S.M. in the building of the ⊜ of Tomorrow, Messrs. Kelly and Kress and Associates, Cleveland's young firm of progressive architects. I've already told you (November 1957 Metal Progress) some of the background and training of the principals, so you are undoubtedly expecting great plans from them and I'm sure you'll not be disappointed. The working drawings are in almost the finished stage and refinements are being developed smoothly and in close cooperation with the builders, Gillmore-Olson Co. of Cleveland.

Inasmuch as the headquarters building is set back about a quarter of a mile from the main highway, the first of the site projects was to construct an "access" road so that the construction material and equipment for the building could be transported to the site at the earliest possible date for the ground-breaking activities. Consequently, the architects laid out a winding entrance road, the builders issued contracts for the construction, and work was started in December. The road is now about finished and a few more days of California weather will permit one to see the finished access road (with exception of the top-finish which will not be placed until just before the opening of the building).

Below is a picture of the retaining wall for the road where it crosses a low spot. Some 15,000 cu. yd. of good earth will be used to bring the road to the main entrance at the second level of the building. At the spot where the earth was lifted there will be a storage reservoir of some 15 million gallons of good old H_2O, to be available for (you guessed it) setups in case of fire, internal or external. We have been assured that if we prepare a concoction of



Retaining Wall for the Entrance Road Shows the Start of Construction of Future ⊜ Headquarters Building

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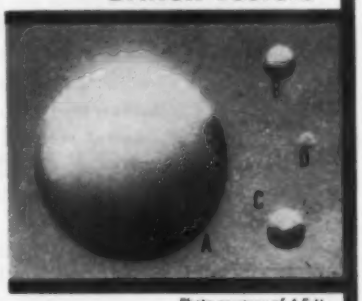

Photo courtesy of A.S.M.

Photograph illustrates the comparative size of impressions made by four different types of hardness tests:

(A) Brinell, (B) Rockwell "B", (C) Rockwell "C", and (D) Scleroscope. Because it covers a larger area, the Brinell impression (A) averages out small inequalities in hardness, surface finish, and complex internal conditions of the metal.

Steel City Brinell Hardness testers are designed to efficiently provide a *true* picture of the hardness of castings, forgings, bars and other comparatively rough and soft forms of metal. Models are available to facilitate the handling of the work with minimum of effort. *True, round Brinell impressions assure dependable testing results.* If a Brinell Hardness test is indicated for your material or product — contact Steel City for the *right* testing machine.

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As I was saying...

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I was telling Mill at some length about the fine volume and quantity of the ⊜ wells and she inquired, "Now Bill, did you strike water or gas?" That slowed me down for a while but after 40 years of married life you get accustomed to these witty pleasantries. So after taking a sip of water, my spirits rose (again) but the only answer I could grab onto was "No such luck."

I hope before very long to be able to present in ⊜ publications a sketch of the model of the headquarters building. At that time I'll have Architect Kelly give you a description that will be understandable when you view the picture of the model. It's really true that one picture is worth 10,000 words. When I talk about the dome that will be the distinguishing feature of the Headquarters (in reality it's an open sculpture of stainless steel and aluminum, 250 ft. in diameter, 110 ft. high at center) it is impossible to describe (even using your arms). The dome is just something you'll have to see in a picture. What we all hope you'll do is visit us in person when it is finished.

This building is to be a monument to you of the A.S.M. It is only possible because of the fine work, efforts, cooperation and unity with which over the past years you have created such a splendid example of service to your Profession and the Industry, so that those who follow you can carry on to greater achievements – the ⊜ of Tomorrow.

Cordially yours,

Bill

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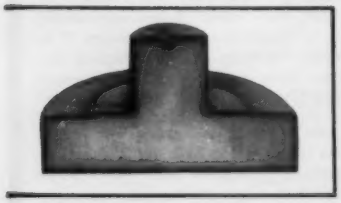

This smooth-cut section of a case-hardened "Rockwell" hardness tester anvil was etched, without finish grind, just as it was taken from submerged cut on CAMPBELL Hudorkut at right.

Cracks due to shaft failure are readily apparent in this hardened steel gear and shaft section cut for metallographic examination while totally submerged on CAMPBELL Hudorkut.

Totally Submerged in Coolant, the Wilson "Rockwell" anvil is shown here as the abrasive wheel (*edge marked*) finishes the cut. Grain structure and hardness of the material have not been disturbed, and the smooth-cut surface was etched, as shown in the picture at left, without the delay of finish grinding.

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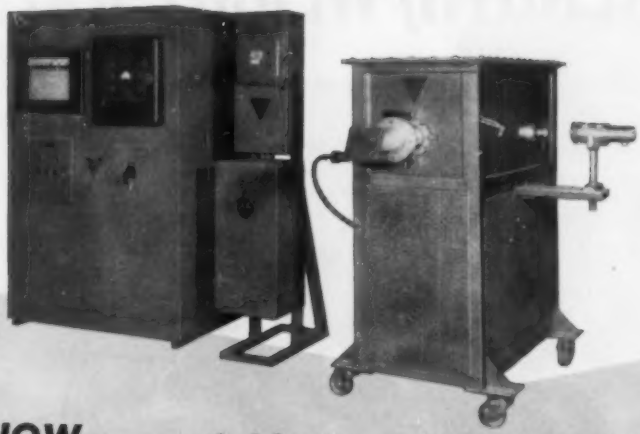

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CT-312	3"	12"	43"	90"	61"	50 KW	5000° F.	5900 lbs.
CT-412	4"	12"	43"	90"	61"	75 KW	5000° F.	6400 lbs.
*CTV-212	2"	12"	35"	45"	86"	30 KW	5000° F.	5450 lbs.
*CTV-312	3"	12"	35"	45"	86"	50 KW	5000° F.	6100 lbs.
*CTV-412	4"	12"	35"	45"	86"	75 KW	5000° F.	6500 lbs.

*"V" indicates the Carbon Tube is in a vertical position.

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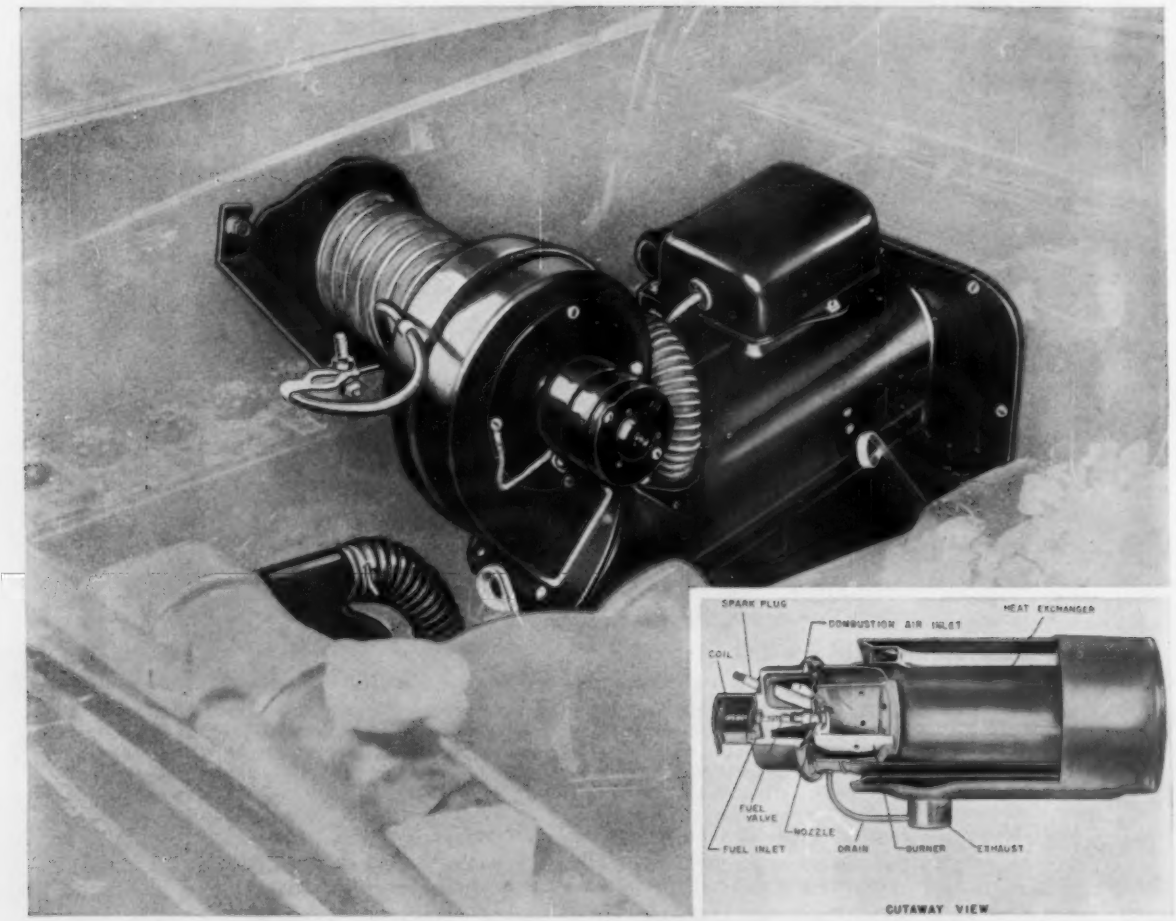

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FOR MAXIMUM SUPPORT, National Seating Company uses Republic ELECTRUNITE® Mechanical Tubing in their "cradle recline" passenger seats. The seat is mounted on 1" O.D. square ELECTRUNITE, bent to a 45° angle for styling. High ductility and superior strength-to-weight ratio of ELECTRUNITE make this operation possible. Rear legs are of ½" x 14-gage round tubing. Besides structural and ornamental advantages, steel tubing eliminates the danger of accidents caused by sharp-edged structural members. Send coupon for complete details on ELECTRUNITE.

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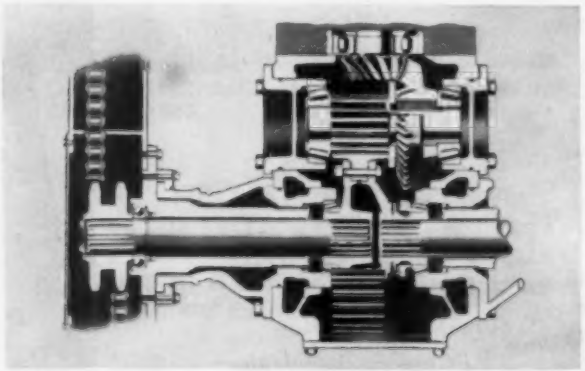

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ELIZABETH 8, N. J.

To Our Friends and Customers

This marks our eightieth year as inventors, developers and manufacturers of industrial gas equipment. In the true spirit of "Pioneering" we have been privileged to have a part in the incomparable development of commercial heat treating equipment.

We wish to express our sincere appreciation to all of our customers who have made our growth possible and also pledge to you that we will continue to permit no compromise in heat treating equipment development as we meet the ever increasing demands of our economy in this "Age of Automation."

Sincerely yours,

AMERICAN GAS FURNACE CO.

Philip C. Osterman

President

AMERICAN GAS FURNACE CO. 80 YEARS OF PIONEERING 1878 1958 ELIZABETH, N. J.

AGF INVENTIONS and DEVELOPMENTS will continue.

since 1878

1. **FIRST** Continuous Type Roller Hearth Heating Machine in 1899.

2. **FIRST** Conveyorized Automatic Heating Machine in 1899.

3. **FIRST** Rotary Retort Heating Machine with atmosphere control in 1902.

4. **FIRST** Automatic Temperature Control Instrument and system developed in 1906.

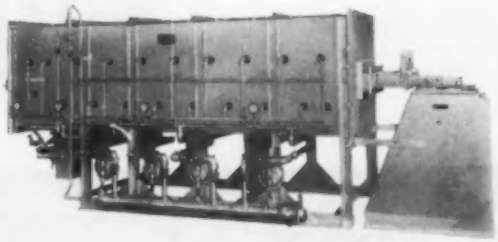
5. **FIRST** to introduce NITRIDING process which employs ammonia to impart a hard wear resistant surface on steel parts at relatively low temperatures and without quenching, in 1913.

6. **FIRST** Automatic Control Shaker Hearth Hardening Furnace in 1921.

7. **FIRST** to introduce and develop the ammonia-gas carburizing process known as Ni-Carbing in 1931.

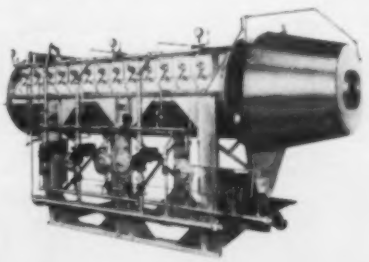
There were many other FIRSTS such as equipment for the electric and electronic industries, as well as chemical process and textile fields.

NOW



AGF Model 240

AGF completely automatic continuous production furnaces for controlled atmosphere heat treating include the model 240 which is only one of several reciprocating or shaker hearths which were introduced since 1921 and have been perfected to achieve positive control of processing temperatures and atmospheres.



AGF
Model 139

AGF Continuous Rotary Retort Furnaces have constantly been improved since their early invention by AGF and now feature automatic operation, easy adaptability to line production, high production at low cost, positive atmosphere control and many other advances.

AMERICAN GAS FURNACE CO.
1002 LAFAYETTE STREET
ELIZABETH, NEW JERSEY

Bulletin No. 80 sent on request.

For whatever you make . . .

N-A-X® HIGH-TENSILE STEEL MEANS LIGHTER WEIGHT WITH LONGER LIFE

Light weight and shallow draft make the ideal commercial river barge. Thanks to the inherent qualities of N-A-X HIGH-TENSILE steel, this river barge designed and built by Nashville Bridge Company, Nashville, Tennessee, offers a weight reduction in excess of 10% over mild carbon steel—plus longer life and increased payload capacity with shallower draft.

Operators like the way weight-saving N-A-X HIGH-TENSILE improves barge towing efficiency—less draft when loaded; less dead weight to pull when empty. That means savings on operating costs all the time. And, again thanks to N-A-X HIGH-TENSILE, barge operators get more resistance to corrosion. For this manufacturing job, like so many others, N-A-X HIGH-TENSILE steel provides desirable lightness with greater durability and strength.

Check These Important Advantages for Your Job: The N-A-X HIGH-STRENGTH steels—both N-A-X HIGH-TENSILE and N-A-X FINEGRAIN—compared with carbon steel, are 50% stronger • have high fatigue life with great toughness • are cold formed readily into difficult stampings • are stable against aging • have greater resistance to abrasion • are readily welded by any process • offer greater paint adhesion • polish to a high luster at minimum cost.

Although N-A-X FINEGRAIN'S resistance to normal atmospheric corrosion is twice that of carbon steel, N-A-X HIGH-TENSILE is recommended where resistance to extreme atmospheric corrosion is important.

For whatever you make, from steel shop boxes to steel river barges, with N-A-X HIGH-STRENGTH steels you can design longer life, and/or less weight and economy into your products. Let us show you how.

This barge, built by Nashville Bridge Company, hauls hot asphalt between Baton Rouge and other points along the Mississippi-Ohio River system. Both the barge hull and the cargo tanks are made of N-A-X HIGH-TENSILE. Weight reduction: in excess of 10% compared with mild carbon steel.

N-A-X HIGH-STRENGTH STEELS

N-A-X Alloy Sales Division, Dept. E-2

GREAT LAKES STEEL CORPORATION

Detroit 29, Michigan • Division of

NATIONAL STEEL CORPORATION

N-A-X Alloy Sales Div., Dept. E-2

Great Lakes Steel Corp., Detroit 29, Michigan

☐ Please send me 12-page illustrated technical catalog on N-A-X HIGH-STRENGTH steels.

☐ Please have your representative contact me.

Name_____ Title_____

Company_____

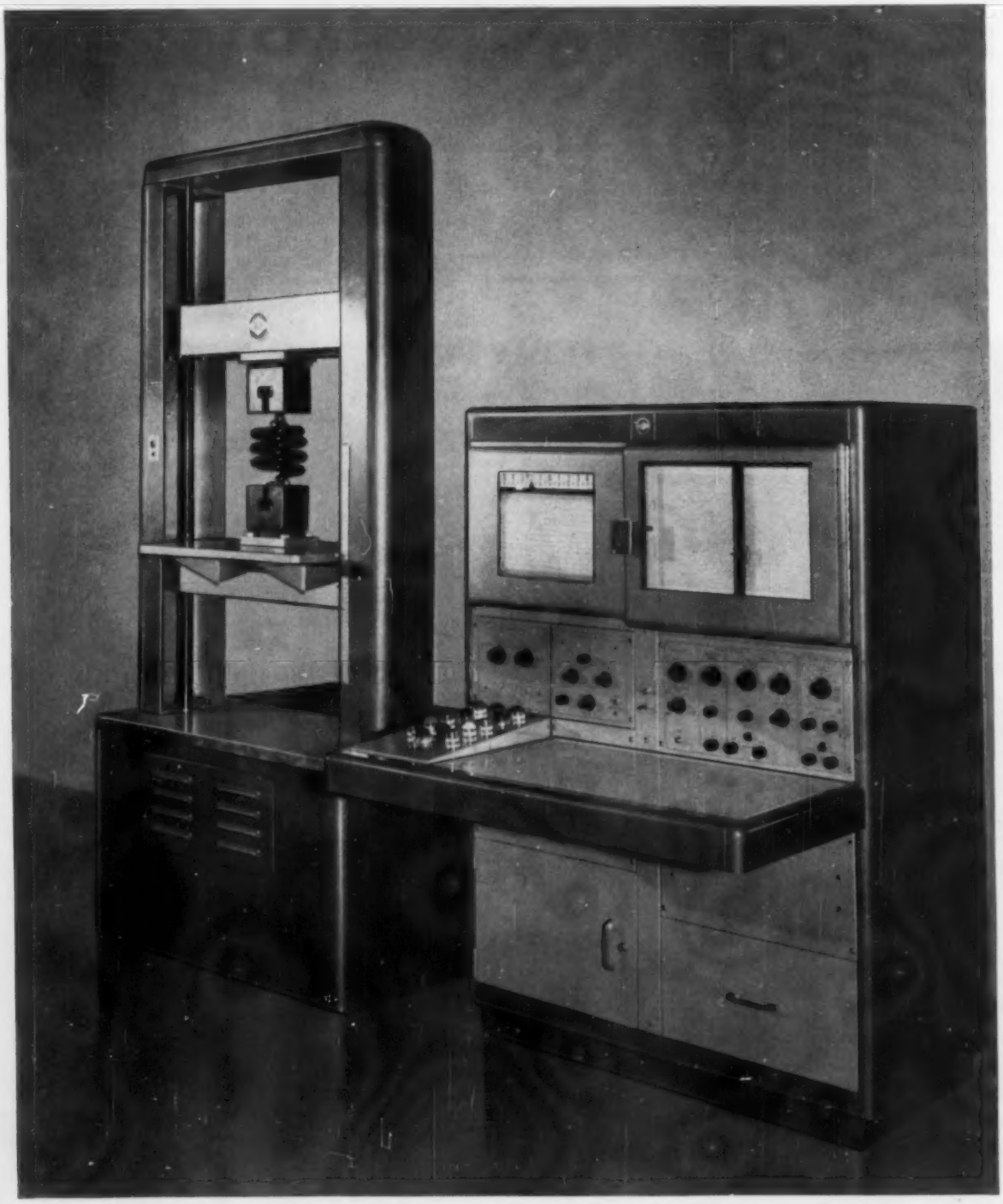
Street_____

City_____ Zone____ State_____

NEWS FROM B-L-H

VERSATILE

SERVOMATIC TESTING MACHINE



MARK G

FEATURES FIXED TEST CENTER

Lightweight, rigid construction—dual platen motion—single space test area—fixed test center for permanent positioning of accessory equipment

The new design and operating principles of the Mark G Servomatic Tester offer versatility and convenience for production and research testing. A wider, more varied range of tests is possible.

The platens of the Mark G, powered by counter-rotating, preloaded ball-bearing screws, move simultaneously in opposite directions. This keeps the test center in fixed position 56½ in. above the floor. Any accessory equipment, such as furnaces, will remain stationary during a test. Strains are electronically measured with high accuracy by built-in SR-4® transducers employing bonded wire strain gages.

The space available for specimens is from 0 to 48 in. and a servocontrolled hydraulic motor moves the platens at speeds up to 20 in. per min. The system self-locks for safety when not running. Electric clutches allow remote speed selection and provide overload protection.

Maximum frame rigidity results from the reduced area occupied by the test load. This is limited to a rectangle formed by the platens and the length of interconnecting screws (determined by the size of the specimen).

The Mark G also offers automatic loading or straining (with SR-4 extensometer), automatic load holding, strain and straining head position holding, and automatic cycling for load or strain in frequencies of from 6/10 to 60 cpm. Two conveniently located built-in sockets permit plug-in of SR-4 strain gages and of microformers or extensometer.

For the best in testing, see B-L-H first. Choose from industry's most complete line of testing equipment—tension, compression, creep, fatigue, impact or torsion. Ask your B-L-H representative about the Mark G Servomatic Tester—or write Dept. 2C for Bulletin #4218.

◀ New Mark G Servomatic Tester and console for tension-compression testing can be ordered in capacities up to 300,000 lb.

Console for Mark G includes instrument controls and two plotters. XY plotter (right) computes crosshead motion vs. load or specimen strain (with use of microformer or SR-4® extensometer) vs. load; a dual pen strip chart recorder (left) graphs load or strain vs. time, works simultaneously with XY plotter. ▶

BALDWIN · LIMA · HAMILTON

Electronics & Instrumentation Division

Waltham, Mass.

Testing machines • SR-4® strain gages • Transducers

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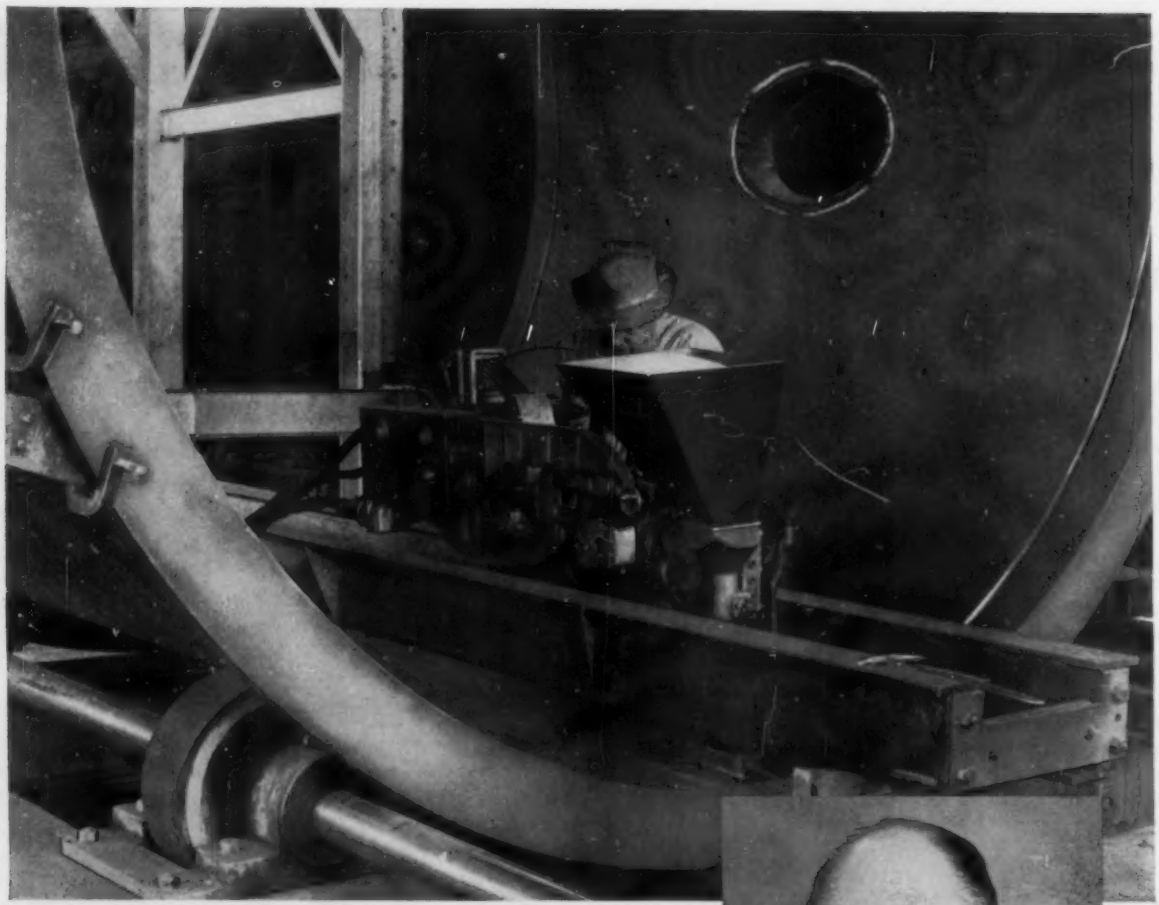


Many of Mine and Smelter's Marcy grinding mills are equipped with Standard Steel flange rings, shown above. No flange ring replacements have ever been required. Some of these mills have been operating 24 hours a day for more than 15 years.

"'Dependability' is the keyword in our very fine relationship with Standard Steel"

We at Standard are happy indeed that Mine & Smelter Supply Co.'s chief engineer, J. R. Grout, appreciates the efforts we have gone to over the years to combine dependable service with our know-how and quality standards.

We consider it our responsibility to help maintain the world-wide reputation for quality mining and industrial equipment which Mine & Smelter Co.'s Marcy Mill Division enjoys by providing this customer with the same fine service it renders, in turn, to *its* customers.

Won't you discuss your needs for weldless rings, flanges, forgings and castings with us. You will appreciate our personalized service. Write Dept. 3-C.

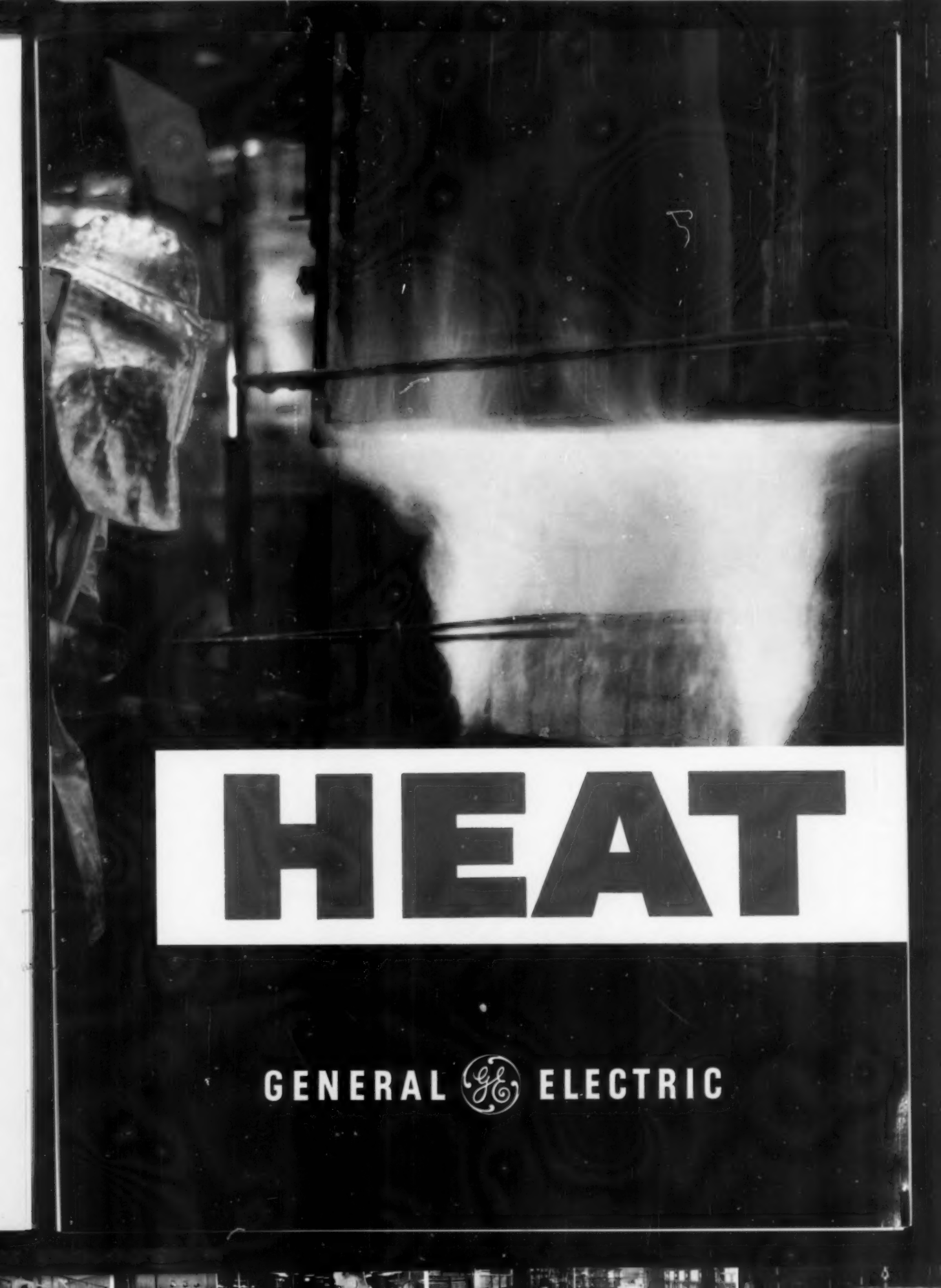
"Standard Steel for many years has been supplying our company with shell flange rings, as well as riding and roller tires for use on our Marcy Grinding Mills and other rotary-type equipment. Their product quality and cooperation have helped make it possible for us to serve our customers promptly—our company policy. I believe the word 'dependability' is the keyword in our very fine relationship with Standard Steel," says Joseph R. Grout, chief engineer, Marcy Mill Division, Mine & Smelter Supply Co.

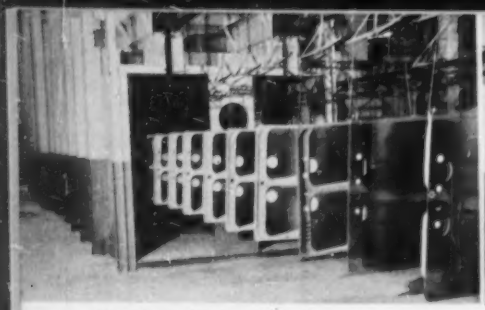
Standard Steel Works Division

BALDWIN · LIMA · HAMILTON

BURNHAM, PENNSYLVANIA

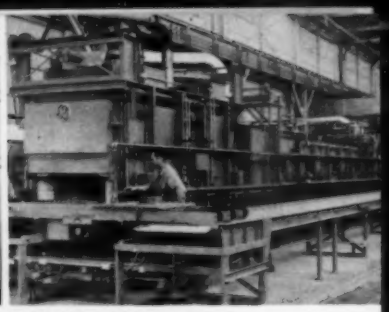
Rings • Shafts • Car wheels • Gear blanks • Flanges • Special shapes


HEAT
GENERAL ELECTRIC

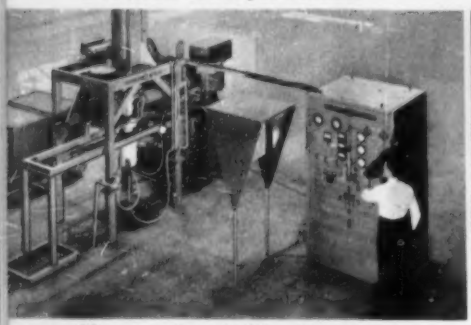


Overhead-conveyor Furnace

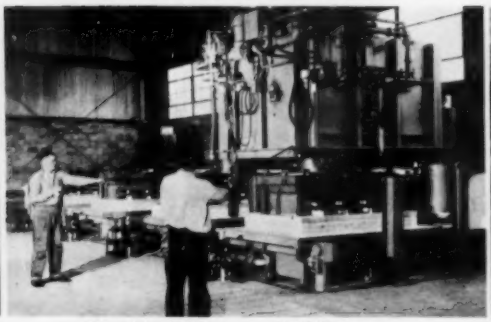
High-temperature Box Furnace



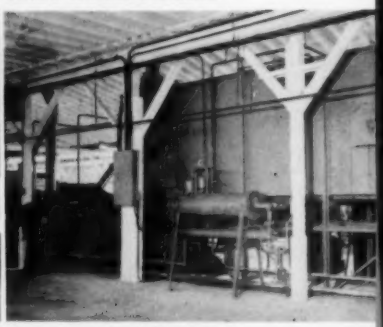
Roller-hearth Furnace



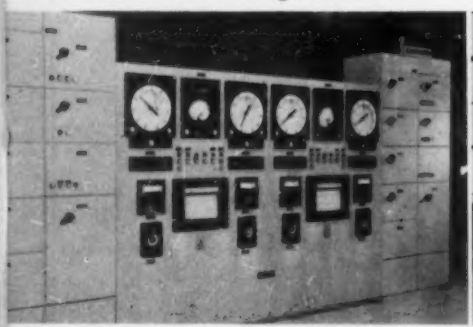
Vacuum Arc Melting Furnace



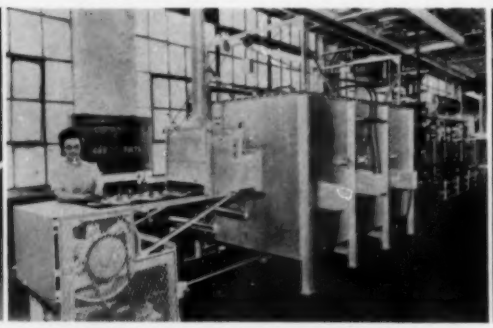
Gas-fired Vacuum Bell Furnace



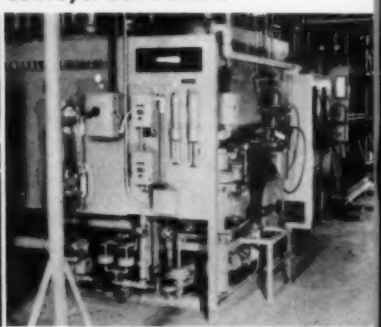
Conveyor Belt Furnace



Heat Processing Control Panel

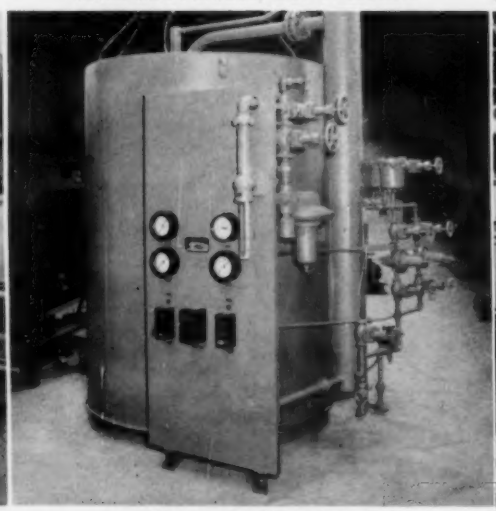


Mesh-belt Furnace, Gas or Electric

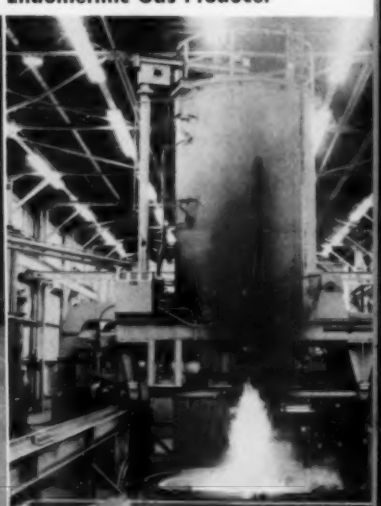


Endothermic Gas Producer

Cylindrical Pit Furnace



Ammonia Dissociator

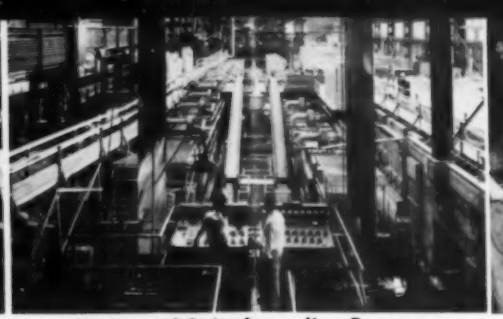


Traveling Cylindrical Furnace

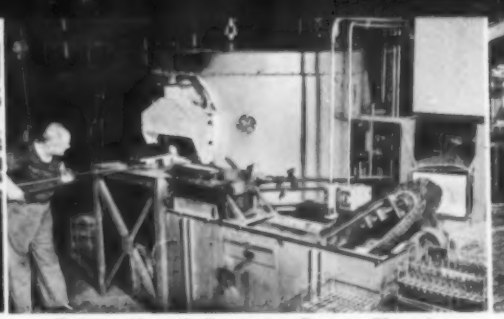
HEAT FOR MANY

Gas-fired Car Bottom Furnace

Electronic Induction Heaters

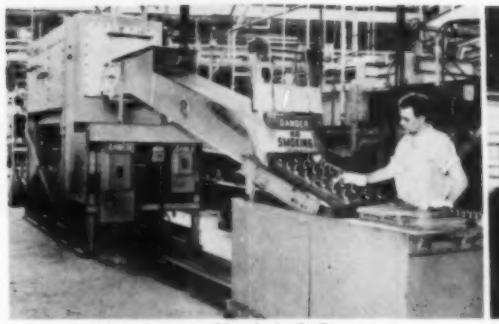


Horizontal Strip Annealing Furnace

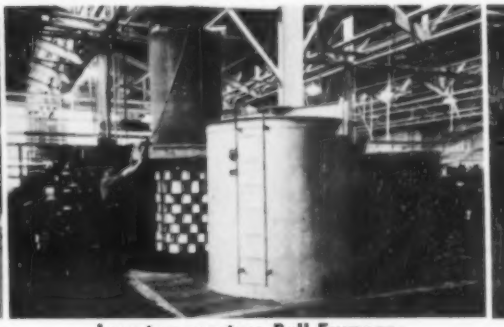


Rotary Hearth Furnace, Gas or Electric

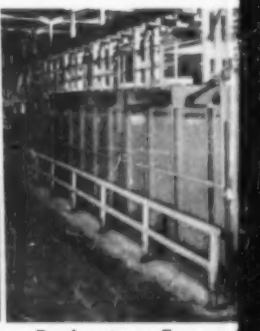
Box Furnac



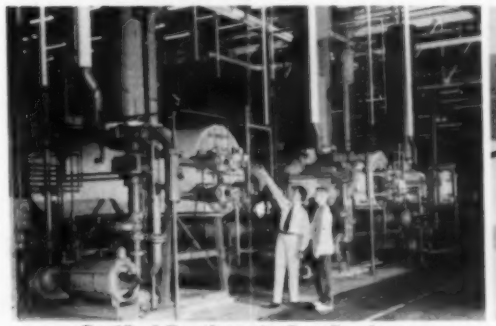
Hump-type Mesh-belt Furnace



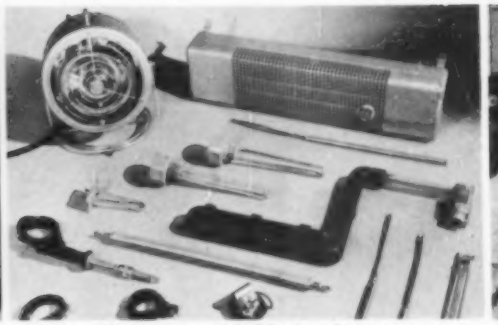
Low-temperature Bell Furnace



Pusher-type Furnace



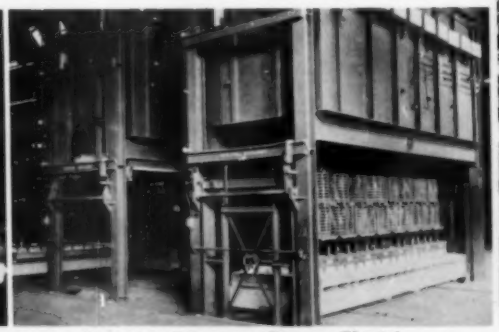
Purified Exothermic Gas Producer



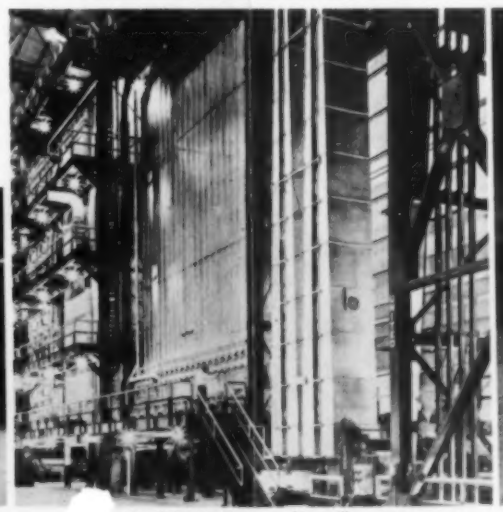
Heaters and Soldering Irons

Box Furnace with C

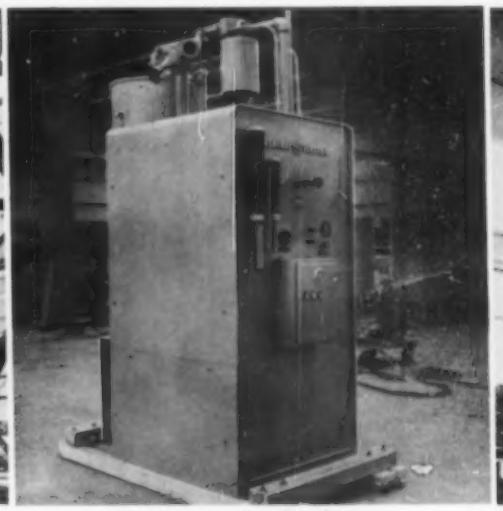
Motor-Generator Induction Heater



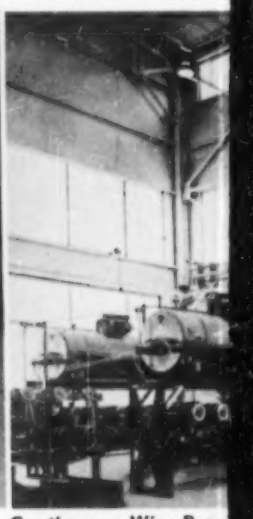
Elevator Furnace, Gas or Electric



ertical Strip Annealing Furnace



Exothermic Gas Producer



Continuous Wire Proc

HERE'S HOW INVESTMENTS IN G-E ELECTRIC, GAS AND INDUCTION HEATING INSTALLATIONS PAY OFF

Heat processing modernizations planned and built by General Electric normally pay for themselves in from two to three years. This means a 30% to 50% return on your invested dollars and heavy contributions to profit when the furnace is paid for. This high return is possible because you can:

Reduce Work spoilage. G-E gas, electric and induction heating equipments give you uniform and consistent high quality. With General Electric equipment, heat processes may be set and controlled within close limits. Little supervision is needed. Human error can be eliminated.

Lower operating costs. Maintenance and operating labor can be placed in more important work.

Increase your sales. Products of improved quality and lower cost help to give you a competitive advantage.

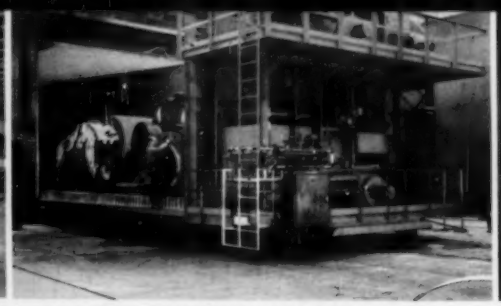
Get fuel economies. Costs of various fuels have changed noticeably in many localities during the past 20 years. Furnaces built in 1938 may not let you take advantage of the most economical heat source in your area today.

Meet specialized needs with General Electric's extensive line of electric furnaces, gas furnaces and induction heaters in many standard sizes, types and ratings.

Are obsolete heat processing equipments reducing your profits? Your present costs can be figured easily and compared with the low costs possible with an integrated heat process system planned by General Electric. For a complete analysis of your heat treating facilities, call your nearest General Electric Apparatus Sales Office. Section 721-10, General Electric Company, Schenectady 5, New York.

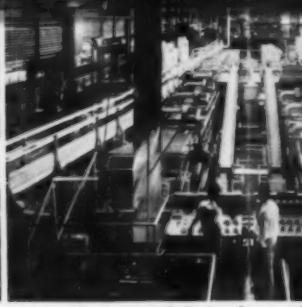
GENERAL ELECTRIC

NEEDS *from* GENERAL ELECTR



Gas-fired Car Bottom Furnace

Electronic Induction Heaters



Horizontal Strip Anneal

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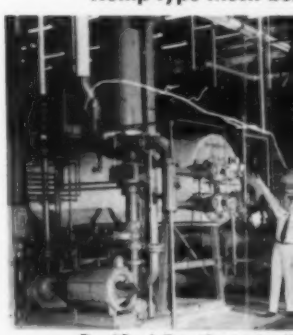
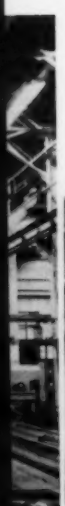
Hump-type Mesh-bel

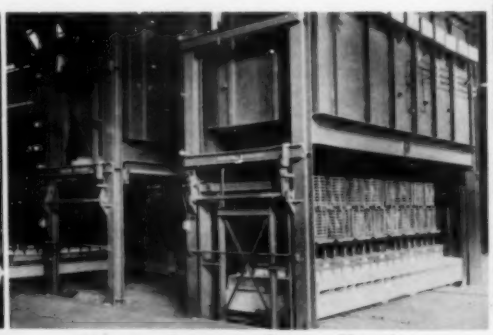


Purified Exothermic G

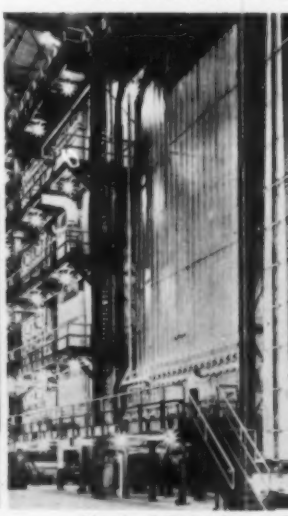
GENERAL ELECTRIC



Motor-Generator Induction Heater

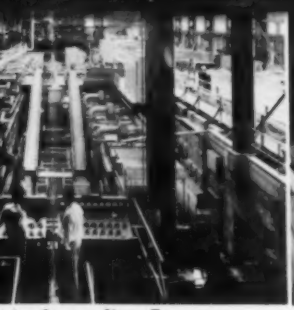


Elevator Furnace, Gas or Electric

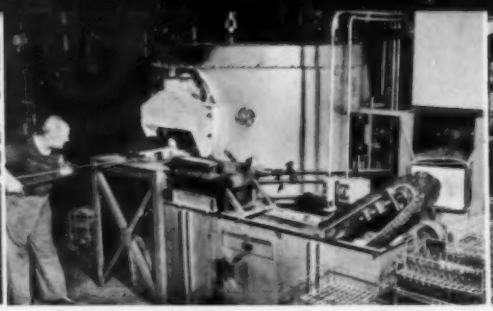


Vertical Strip Anneal

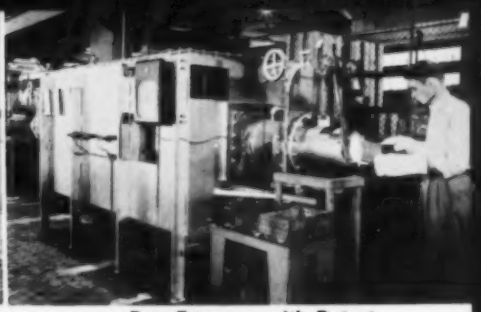
NEEDS *from* GENE



trip Annealing Furnace

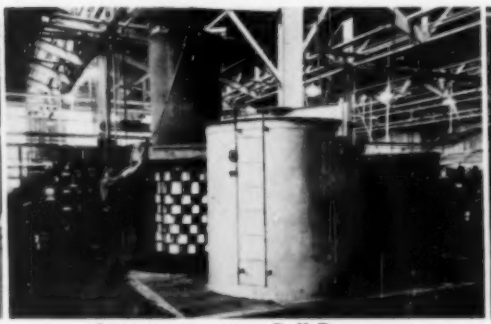


Rotary Hearth Furnace, Gas or Electric

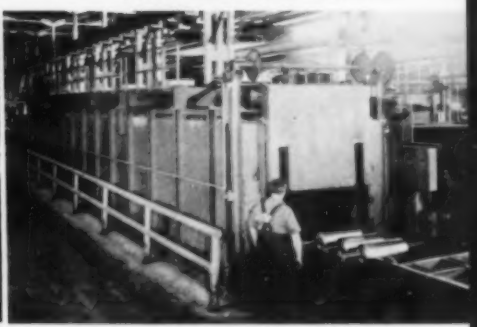


Box Furnace with Retort

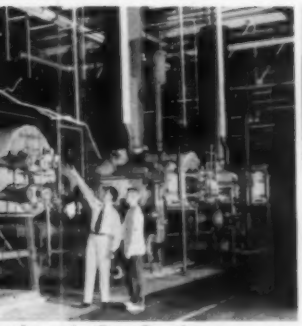
e Mesh-belt Furnace



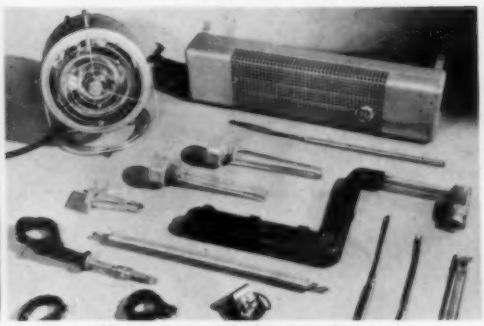
Low-temperature Bell Furnace



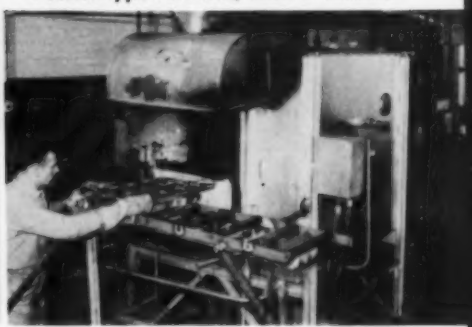
Pusher-type Furnace, Gas or Electric



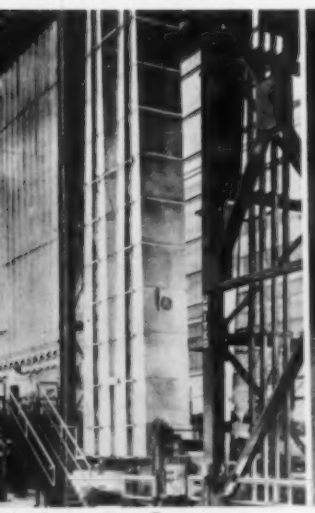
othermic Gas Producer



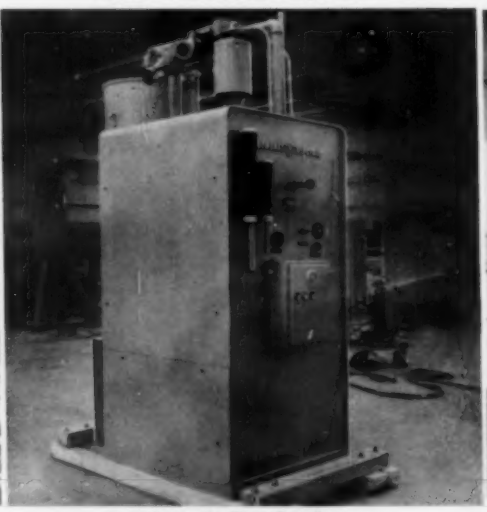
Heaters and Soldering Irons



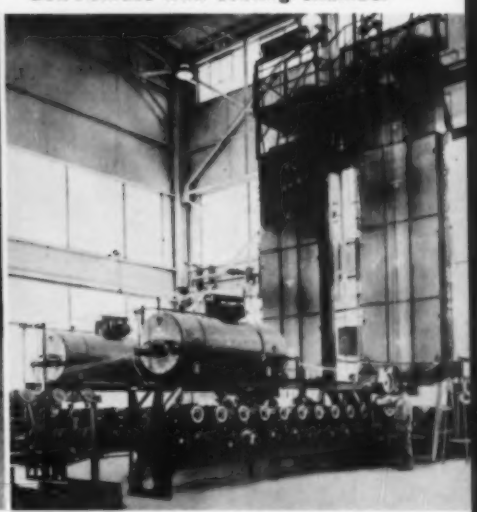
Box Furnace with Cooling Chamber



trip Annealing Furnace

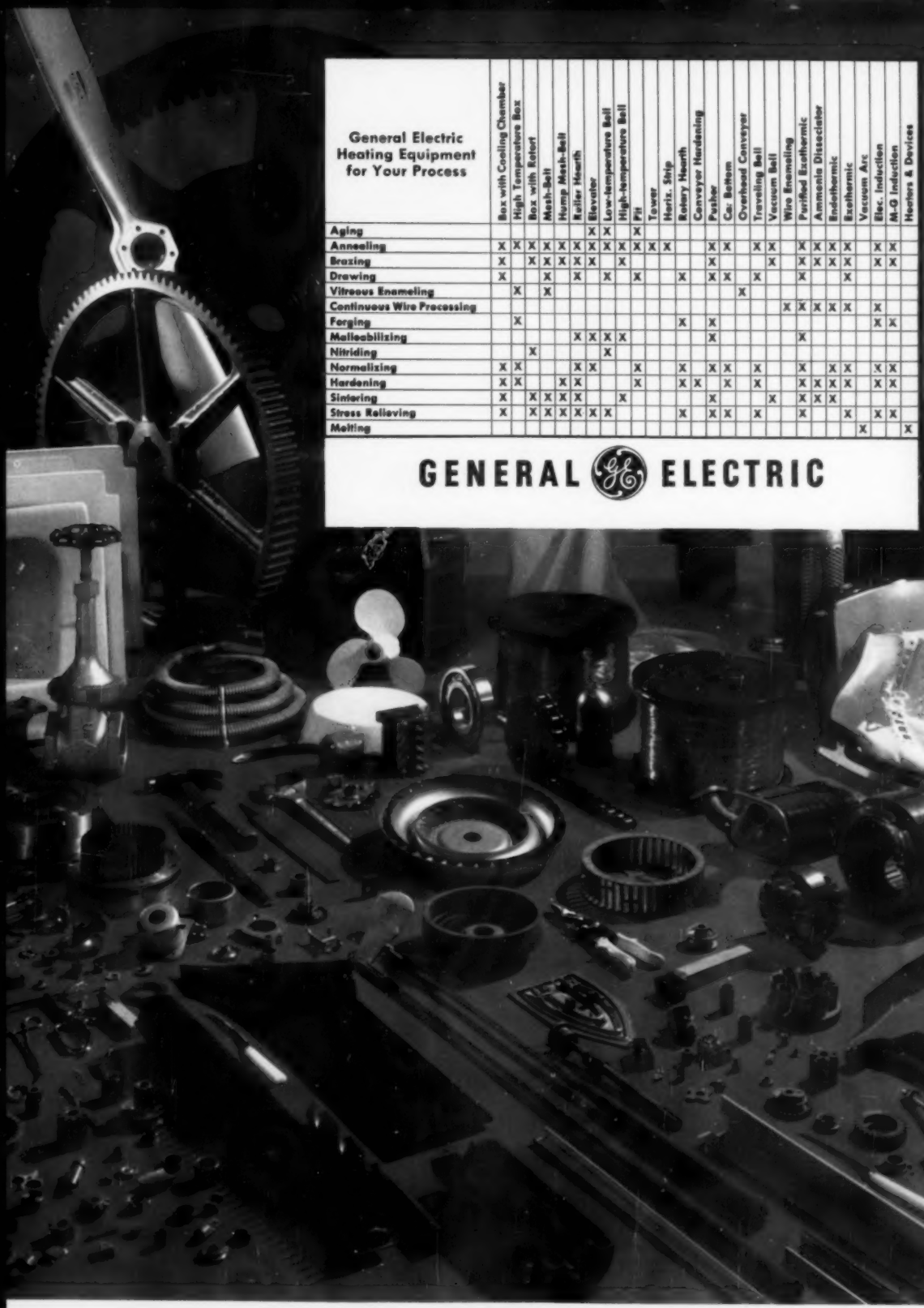


Exothermic Gas Producer



Continuous Wire Processing Equipment

NERAL ELECTRIC



General Electric Heating Equipment for Your Process	Box with Cooling Chamber	High Temperature Box	Box with Retort	Mesh-Belt	Hump Mesh-Belt	Roller Hearth	Elevator	Low-temperature Bell	High-temperature Bell	Pit	Tower	Horiz. Strip	Rotary Hearth	Conveyor Hardening	Pusher	Ca: Bottom	Overhead Conveyor	Traveling Bell	Vacuum Bell	Wire Enameling	Purified Exothermic	Ammonia Dissociator	Endothermic	Exothermic	Vacuum Arc	Elec. Induction	M-G Induction	Heaters & Devices
Aging							X	X		X																		
Annealing	X	X	X	X	X	X	X	X	X	X	X	X			X	X		X	X		X	X	X	X		X	X	
Brazing	X		X	X	X	X	X		X						X				X		X	X	X	X		X	X	
Drawing	X			X		X		X		X			X		X	X		X			X			X				
Vitreous Enameling		X		X													X											
Continuous Wire Processing																				X	X	X	X	X		X		
Forging		X											X		X											X	X	
Malleabilizing							X	X	X	X					X						X							
Nitriding				X				X																				
Normalizing	X	X					X	X			X			X		X	X		X			X		X	X		X	X	
Hardening	X	X				X	X				X			X	X		X		X			X	X	X	X		X	X	
Sintering	X			X	X	X	X			X						X				X		X	X	X					
Stress Relieving	X			X	X	X	X	X	X					X		X	X		X			X			X		X	X	
Melting																										X			X

GENERAL ELECTRIC

APPLICATIONS

	Elec. Induction	M-G Induction	Heaters & Devices
		X	X
		X	X
	X		
		X	X
	X	X	
		X	X
	X	X	
			X

ALL OF THIS LITERATURE IS AVAILABLE FROM GENERAL ELECTRIC

- ☐ Furnace and Induction Brazing, GEA-5889
- ☐ How and where to use Electric-furnace Brazing, GEA-3193
- ☐ How to Braze Stainless Steel, GER-1331
- ☐ Heat Treating Aluminum, GEA-5912
- ☐ Annealing of Malleable Iron, GEA-5797
- ☐ How to Get the Best Results from Sintering Furnaces, GER-978
- ☐ Temperature Control of Heat Treating Furnaces, GER-1206
- ☐ Protective Atmospheres for use with Industrial Furnaces, GEA-5907
- ☐ New General Electric Induction Heaters, GEA-6388
- ☐ Catalog of General Electric Heaters and Devices, GEC-1005

SECTION 721-10
GENERAL ELECTRIC COMPANY
SCHENECTADY 5, NEW YORK

Please send me the following bulletins.

GEA-....., ..., ..., ..., ...,

GER-....., ..., ..., GEC-.....,

NAME.....

TITLE.....

COMPANY.....

ADDRESS.....

CITY.....STATE.....

G-E MATERIALS HANDLING SYSTEMS SPEED PRODUCTION

Modernization and mechanization of heat processing systems speed production, give uniformity of product, improve quality, and reduce your manufacturing costs. General Electric can supply materials handling equipment, atmosphere producers, instruments, quenching equipments and furnaces or induction heaters to give you "one source" responsibility for your heat treating line.

FACTORY ASSEMBLY REDUCES YOUR INSTALLATION TIME

General Electric can completely assemble large furnaces in its Shelbyville, Indiana plant. This means that when you buy from General Electric you can have your piped and wired furnace on the line more quickly and with lower over-all first cost. Experienced furnace builders handle every step of construction and General Electric provides either supervision or complete installation at your plant.

Progress Is Our Most Important Product

GENERAL ELECTRIC

C. G. Hussey & Company, Pittsburgh, solved a number of copper annealing furnace problems with help from the MSA Instrument Specialist (right), and this Inert Gas Analyzer.

M-S-A® Inert Gas Analyzer eliminates bad heats automatically—assures clear, bright, smooth product

Product uniformity is now continuously and automatically controlled in the C. G. Hussey & Company annealing process. An M-S-A Inert Gas Analyzer with control mechanism has taken over the job.

Before the instrument was installed, the ratio of gases used in the annealing process was maintained by manual controls. The operator had to watch or spot-check analysis instruments. Quality of the resultant atmosphere in the furnace often varied from the range needed for product uniformity.

But now, according to L. A. O'Donnell, superintendent of the heat treating and annealing department: "We haven't had a bad heat since we installed the system. And there's been no major maintenance on the analyzer since it has been in use." In addition to the analyzer on the gas-fired annealing furnace, Hussey & Company also has two others for control of electric furnace atmospheres.

In the Hussey & Company annealing process, the product is heated to annealing temperature while blanketed with an inert gas atmosphere. This atmosphere must be free of oxygen and low in hydrogen to prevent spoiling the product. That's why the M-S-A Inert Gas Analyzer is so vital here. It controls atmosphere to very close limits, records atmosphere quality.

Perhaps this low-cost, low-maintenance instrument has a place in your quality control program. An MSA Instrument Specialist will be pleased to discuss your specific problems with you. Write for information regarding your specific problems of atmosphere analysis and control.

MSA INSTRUMENT DIVISION

MINE SAFETY APPLIANCES COMPANY

Pittsburgh 8, Pennsylvania

NORTHWEST
LEADS THE WAY WITH CHEMICALS FOR USE WITH
ALUMINUM

If you work with aluminum you'll be interested in Northwest's outstanding line of chemicals for use with modern alloys. Northwest's continuing research and development program has earned them the reputation of "First with the best" in this rapidly developing field. It will pay you to investigate:

REMEMBER!

"Your cost per finished article is the true cost of your cleaner."

- **ALKALUME CLEANERS**—A full line of cleaners and etching compounds especially formulated for use on aluminum alloys prior to plating, anodizing, painting or welding.
- **ALKALUME PRE-PLATE**— An especially effective zincate bath for preparing aluminum for plating.
- **ANOSTRIP**—An easily handled liquid product, excellent for stripping anodic film from aluminum surfaces and racks without damage.
- **ALKALUME DS**— An efficient, economical, 100% active product for removal of etching smut at room temperature.

Northwest products are manufactured on the West Coast by
ALERT SUPPLY COMPANY, Los Angeles

NORTHWEST CHEMICAL CO.
9310 ROSELAWN DETROIT 4, MICH.

"We have been well pleased..."

writes a foremost manufacturer about the metal-melting protection of Norton refractories

High melting, long-lasting ALUNDUM*, CRYSTOLON*, MAGNORITE*, FUSED STABILIZED ZIRCONIA and other Norton refractory materials are Norton Rx's — *engineered and prescribed* for longer, lower cost service across the range of furnace applications.

For Rx's that will help you maintain hot metal schedules and reduce shutdowns in your own processing, call in your Norton Refractories Engineer. Or write to NORTON COMPANY, Refractories Division, 322 Bond St., Worcester 6, Mass.

NORTON
REFRACTORIES
Engineered... Rx ...Prescribed

Making better products... to make your products better

NORTON PRODUCTS
Abrasives • Grinding Wheels
Grinding Machines • Refractories
BEHR-MANNING DIVISION
Coated Abrasives • Sharpening Stones
Behr-cat Tapes

*Trade-Marks Reg. U. S. Pat. Off. and Foreign Countries

VACUUM METALS CORPORATION
DIVISION OF CRUCIBLE STEEL COMPANY OF AMERICA
P. O. BOX 977 SYRACUSE 1, N. Y.
SYRACUSE 8-2871

March 27, 1957

Norton Company
Worcester 6
Massachusetts

Gentlemen:

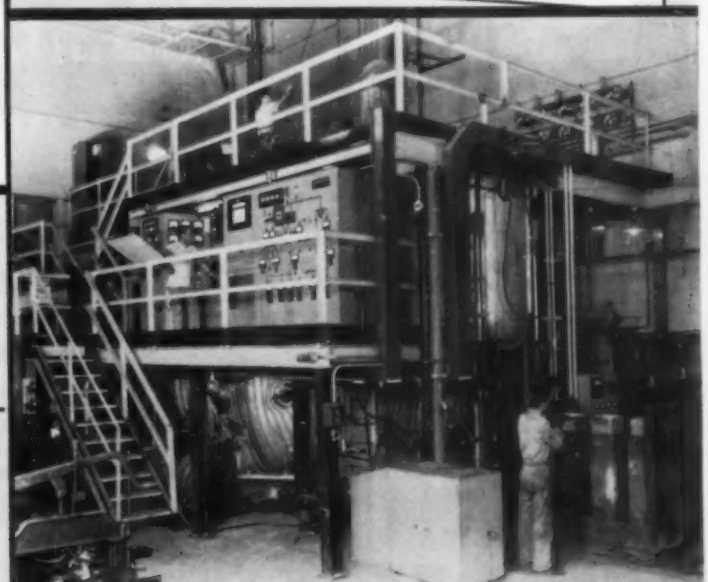
I am enclosing a general view of our newest vacuum melting furnace and a view of the crucible during a melt. This furnace is the largest high vacuum induction furnace in the country and has a capacity of 3000 pounds per heat.

We have successfully used a Norton ramming mix for rammed linings in this and in our 700 pound furnace. Your prefired shapes of Magnorite and Alundum have been used for pouring lips and pouring tubes. Your refractory ramming mixes have been used as a backing for Norton Magnorite and Alundum crucibles in laboratory furnaces for nearly ten years. We have been well pleased with the quality and performance of your products.

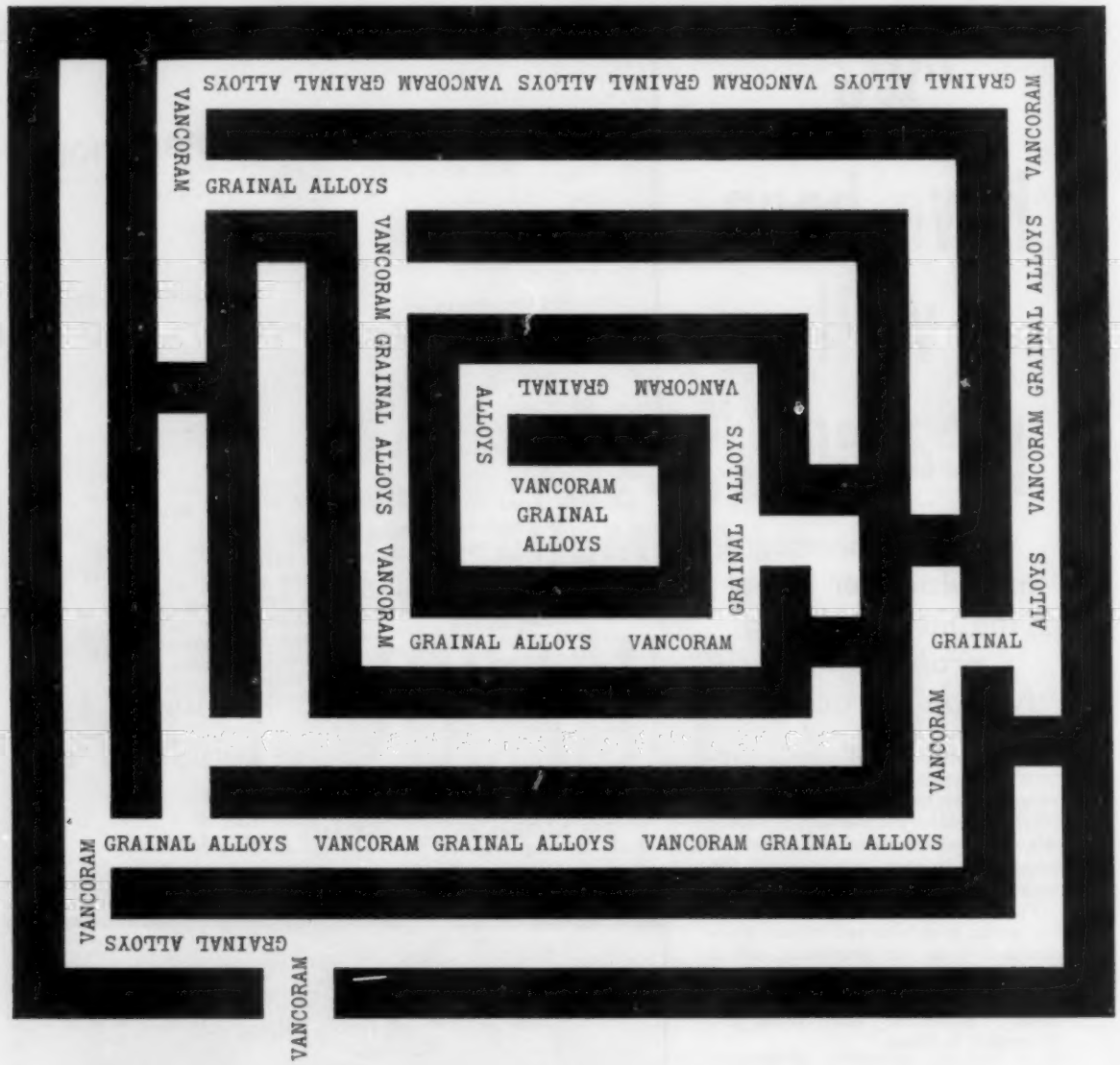
Very truly yours,

A. E. Franks
Division Superintendent

AEF/a
cc: Michael Stumm



Largest of all high vacuum induction furnaces in the U.S. The accompanying letter from Vacuum Metals Corporation, a Division of Crucible Steel Company, describes how Norton refractory cements and prefired shapes aid in the advanced performance of this huge, modern metal-melting equipment.



EASIEST SOLUTION TO MANY PROBLEMS! Grainal was first introduced in 1938 as a hardenability intensifier. Since then it has been used in millions of tons of steel.

In recent years, Grainal Alloys have become increasingly important in stainless and heat-resisting steels where they improve hot-working characteristics and reduce conditioning costs and rejections.

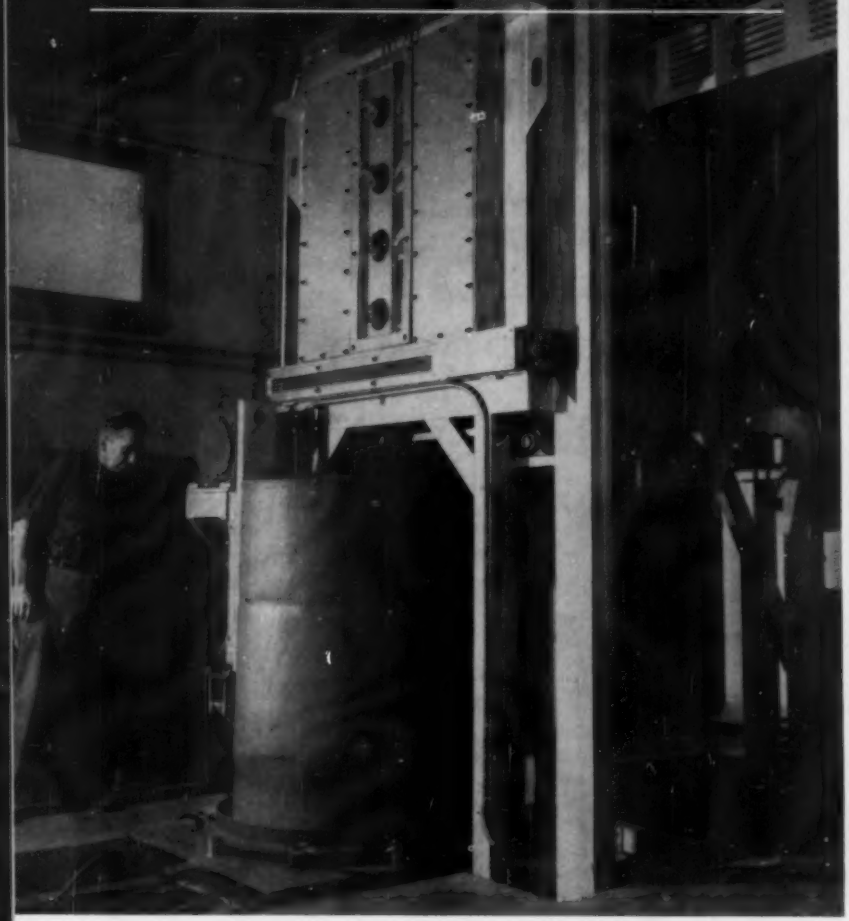
Grainal Alloys improve the physical properties of high-strength cast steels. They are also used in cast steels as a special deoxidizer.

Call your nearest VCA office to learn more about these *versatile* alloys . . . or write for the informative pamphlet — "Grainal and Its Use." Vanadium Corporation of America, 420 Lexington Avenue, New York 17, N. Y.

Producers of alloys, metals and chemicals

VANADIUM CORPORATION OF AMERICA

PRODUCING MISSILE COMPONENTS:



STAINLESS BRAZING PROBLEMS LICKED

By assembling inexpensively-produced components and then brazing them in this Harper Elevator Furnace, Fabriform Metal Products, Inc., Los Angeles, has by-passed high manufacturing costs. Forging, casting and excessive machining have been eliminated in producing a tremendous variety of complicated products . . . including stainless missile and jet engine parts.

Operated on a two-shift basis, the Harper Furnace has not only proved extremely versatile, but has enabled Fabriform to overcome many tough brazing problems. Even metal working dies and molds of tool steel have been copper brazed without decarburization. Recently, a thousand stainless steel bearing housings were copper brazed with only one reject in the lot. Relatively heavy sections of difficult-to-braze super alloys such as A-286 and Inconel X have been handled successfully. Excellent results have been obtained using a variety of base metals, as well as filler metals including nickel-base alloys.

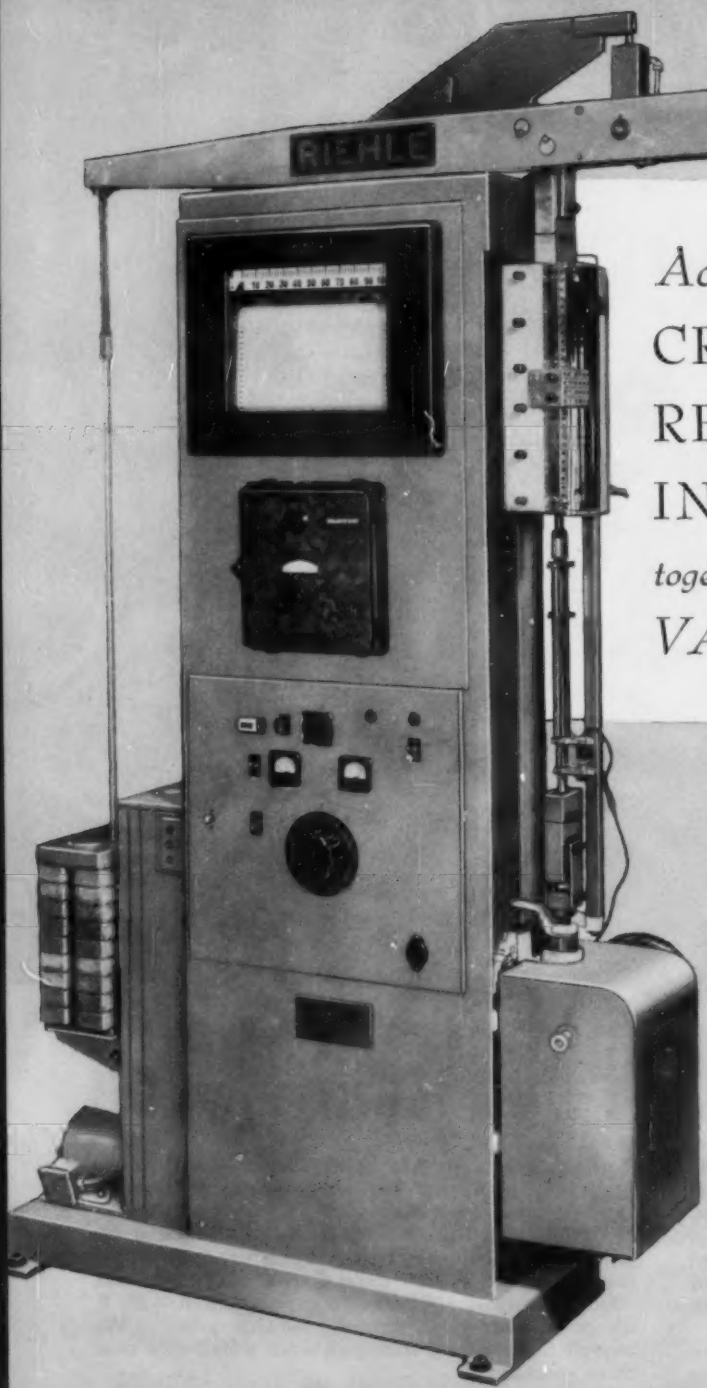
With the furnace capable of holding a ton of parts stacked 30″ high within a 24″ diameter, temperatures up to 2100 F can be attained in the inconel retort. Temperature uniformity is excellent: Placed within loads 20″ high, matched thermocouples show no temperature differences.

"The Harper Furnace is extremely flexible and can produce practically any time-temperature cycle within reason," says A. M. Thompson, Gen. Mgr. of Fabriform. "Because we can hold effluent dew points of —90 F, it's possible to do extremely difficult jobs . . . We haven't had a forced shutdown since installation over three years ago."

To reap the maximum benefits of furnace brazing, you'll find it pays to talk to a Harper representative . . . for Harper can build the furnace best suited to your needs: box, pusher, mesh belt, roller hearth, bell, elevator or pit. For detailed information, write: Harper Electric Furnace Corp., 40 River St., Buffalo 2, N. Y.

HARPER ELECTRIC FURNACES

FOR BRAZING, SINTERING, WIRE ANNEALING, BRIGHT ANNEALING, FORGING AND RESEARCH



Accommodates complete

CREEP RECORDING INSTRUMENTATION

together with

VACUUM FURNACE

Creep and stress rupture testing of materials at temperatures to 2000° F., in vacuums to 1 x 10^{-5} mm Hg, can be performed on the Riehle creep testing machine when equipped with a recently developed vacuum furnace. Creep measuring equipment employing electronic recording of specimen strain is provided.

Programmed tests for both creep and relaxation and under vacuum furnace conditions may also be made on the Riehle Universal Testing machines of any capacity with equipment and instruments available.

Convenience in observation and operation is assured because both the elevated temperature equipment and recording instrumentation are designed to function as an integral part of the Riehle machine.

Other Riehle Testing Machines: *Hydraulic and Screw Power Universal Testing Machines, Hydraulic Fatigue Testing Machines, Construction Materials, Impact, Brinell, Torsion, Horizontal Chain, Rope and Cable Testers, Portable Hardness Testers for Rockwell Readings, Etc.*

Free Bulletin . . . Mail Coupon

Riehle TESTING MACHINES

A DIVISION OF

American Machine and Metals, Inc.

EAST MOLINE, ILLINOIS

"One test is worth a thousand expert opinions"

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Division of American Machine and Metals, Inc.
Dept. MP-358, East Moline, Illinois

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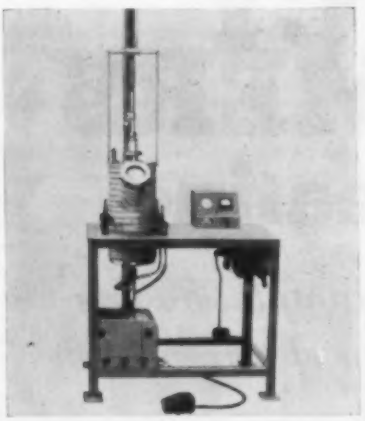
ATTENTION MR.

APPLICATION and EQUIPMENT new products

Vacuum Melting

A new laboratory vacuum arc melting furnace for melting, alloying, consolidating or refining very high temperature metals and alloys has been announced by the Vacuum Equipment Div. of the New York Air Brake Co. This furnace can employ



either consumable or non-consumable electrodes. The standard hearth handles a ½ lb. titanium test button, or equivalent volume of other metals. A hearth having a maximum capacity of 3 lb. can be supplied. The system can be arranged with special valving to hold the pressure at any desired level from 2 psi. above atmospheric pressure down to a vacuum of 10 microns.

For further information circle No. 478 on literature request card, page 48-B.

Aluminizing

The Upton Electric Furnace Co. has announced the development of a new process for coating steel with aluminum while both metals are heated to temperatures ranging from 1300 to 1650° F. The new process uses an electric salt bath furnace. Pure aluminum is melted and floated upon a barium chloride base in the bath or pot of the furnace, and a flux is floated on top of the aluminum. Steel to be aluminized is then dipped in and out of this bath and immediately transferred into another furnace at the same temperature but containing molten salt only. Here, it is dipped in and out to smooth out the aluminum and remove the flux. Penetration of the aluminum is controlled by the furnace temperature to 0.003 to 0.010 in.

For further information circle No. 479 on literature request card, page 48-B.

Blast Cleaning

Pangborn Corp. has announced a new 72 cu. ft. Rotoblast barrel to blast clean castings, forgings and heat treated parts weighing up to 6 tons in 5 min. It is equipped with two Rotoblast wheels, each capable of throwing 120,000 lb. of abrasive per hour. Each wheel is powered by a 40 hp. motor. Heavy-duty motors also power the shaker conveyor, the barrel door and the abrasive elevator. All operations of the new barrel including loading, starting, stopping and unloading are automatic. Wheel housings and blast chamber are lined with replaceable wear-resist alloy plates. An abrasive cleaning, recleaning system removes all sand and debris. Scale, dust and broken-down abrasives

are removed from the abrasive after which it is returned to the Rotoblast wheel for reuse.

For further information circle No. 480 on literature request card, page 48-B.

Rolling Metal Powders

A new horizontal rolling mill which compacts metal powders directly into sheet and strip has been announced by Stanat Manufacturing Co. It is convertible to a vertical 2-high, 4-high combination mill. The mill will produce both ferrous and nonferrous materials in widths up to 7 in. and thick-

nesses ranging from 1/32 to ⅛ in., depending on the particular metal powder being processed. The new mill can be used for both hot and cold rolling operations. The metal powder is poured between revolving rolls and a solid, uniform mass produced. Roll diameter, roll gap and roll speed determine strip qualities. Laminations may be produced by directing streams of dissimilar powders into the roll gap. Powder may also be compacted between strips of wrought metal to form a sandwich. Practically all metal powders compacted into strip must be sintered within a protective atmosphere such as hydrogen or argon to increase strength and ductility. The process is usually completed by rerolling the sintered strip in either a 2-high or 4-high rolling mill.

For further information circle No. 481 on literature request card, page 48-B.

Freezer

A new 5-cu. ft. low-temperature chilling and refrigeration machine has been announced by Harris Refrigeration Co. The new unit requires 44 by 30 in. of floor space and is completely automatic. The chilling chamber has a working area of 30 by 18 by 16 in., with double walls of 16-gage steel, electrically welded and finished with a coating of hot-sprayed zinc. The refrigerant is channeled through honeycombed, embossed passes which

FIRST to develop the ELECTRONIC Induction Heating Generator

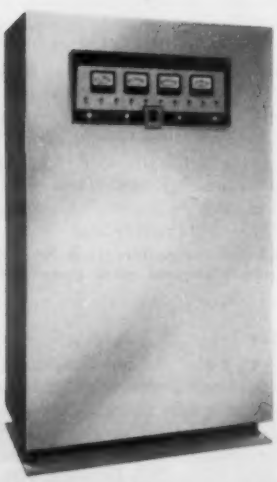
THER-MONIC

announces another first

FREQUENCY TRANSFORMERS*

for Induction Heating

based on a new power conversion principle, having no moving or rotating parts, spark gaps or electronic tubes!



This new principle, developed after several years of intensive research, brings you a simpler type of induction heating power for brazing, soldering, hardening, annealing, forging and melting applications.

Frequency Transformers convert 3-phase, 60-cycle power to single-phase, 180-cycle output by means of conventional capacitors and a transformer-like device. Units ranging from 50 to 250 KW output are available.

DEPTH OF PENETRATION for 180 cycles is greater than for higher frequencies. This has the advantage of reducing heating time in larger sections, because the heat is generated at greater depths in the work. However, there is a limitation as to the minimum size of the work that can be efficiently heated.

INITIAL EQUIPMENT COSTS ARE LOWER, due to the simplicity of construction of Frequency Transformers.

MAINTENANCE COSTS ARE LOWER, because of the absence of moving or rotating parts.

SAFETY OF OPERATION. Besides the absence of moving parts, Frequency Transformers have another inherent safety feature: a short circuit of the work coil or an overload merely results in practically zero secondary voltage, and both primary and secondary windings remain within safe current limits.

QUIET OPERATION. Frequency Transformers reduce the noise level, an important factor in the modern plant, for the relation of this element to personnel efficiency is now well known.

We at THER-MONIC will be glad to discuss with you the application of Frequency Transformers to your particular induction heating requirements. Your inquiry is invited.

INDUCTION HEATING CORPORATION

181 WYTHE AVENUE, BROOKLYN 11, N.Y.

Producers of the most complete line of induction heating equipment for BRAZING, SOLDERING, HARDENING, ANNEALING, FORGING, and MELTING APPLICATIONS

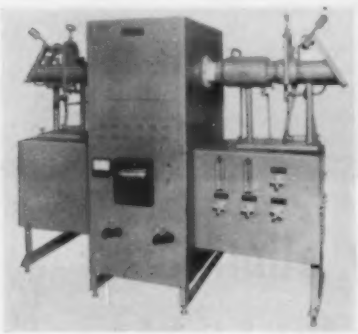
* Pat. Pending

provide direct refrigerant contact with 96% of the cooling chamber surface. Chamber walls are insulated with 5 in. of silica aerogel. The freezer will maintain temperatures from −70 to −130° F.

For further information circle No. 482 on literature request card, page 48-B.

Atmosphere Furnace

A new high temperature atmosphere tube furnace has been announced by the Lindberg Engineering Co. The Type GT-34 furnace is equipped with a 4-in. i.d. metal-ceramic tube assembly, with blast



gates and automatic flame curtains at both ends. It will perform heat treating under a protective atmosphere at temperatures up to 2750° F. A water-jacketed cooling chamber cools the work under a protective atmosphere.

For further information circle No. 483 on literature request card, page 48-B.

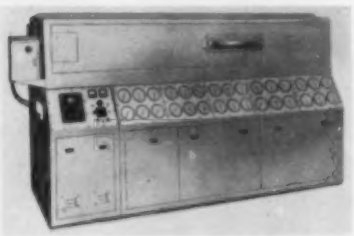
Seamless Tubing

Summerill Stainless Tube Div. has announced a new seamless stainless tubing which is mandrel drawn in sizes from ⅜ to 1½ in. outside diameter and 0.020 to 0.109 in. wall thickness. Because it is finished inside as well as out, it is recommended for heat exchangers, condensers, chemical apparatus, paper mills, aircraft hydraulic lines, and equipment for the atomic energy industry. The production process begins with cold reduction on a tube reducing machine. The material is then bright annealed. After the annealing process, the tubing is lubricated for its passes on the draw bench. It is drawn through a die and over a mandrel at the same time, finishing both the interior and exterior walls.

For further information circle No. 484 on literature request card, page 48-B.

Spectrometer

A new direct reading spectrometer has been announced by the Jarrell-Ash Co. It analyzes ferrous and non-ferrous metals and alloys for up to



30 alloying elements in 30 sec. The 2.5 meter Atomcounter has a pulse-computer electronic measuring system and a two-level dual-deck optical system. Instrument design permits optional film recording of the analytical spectrum as well as direct reading analysis.

For further information circle No. 485 on literature request card, page 48-B.

Chemical Polishing

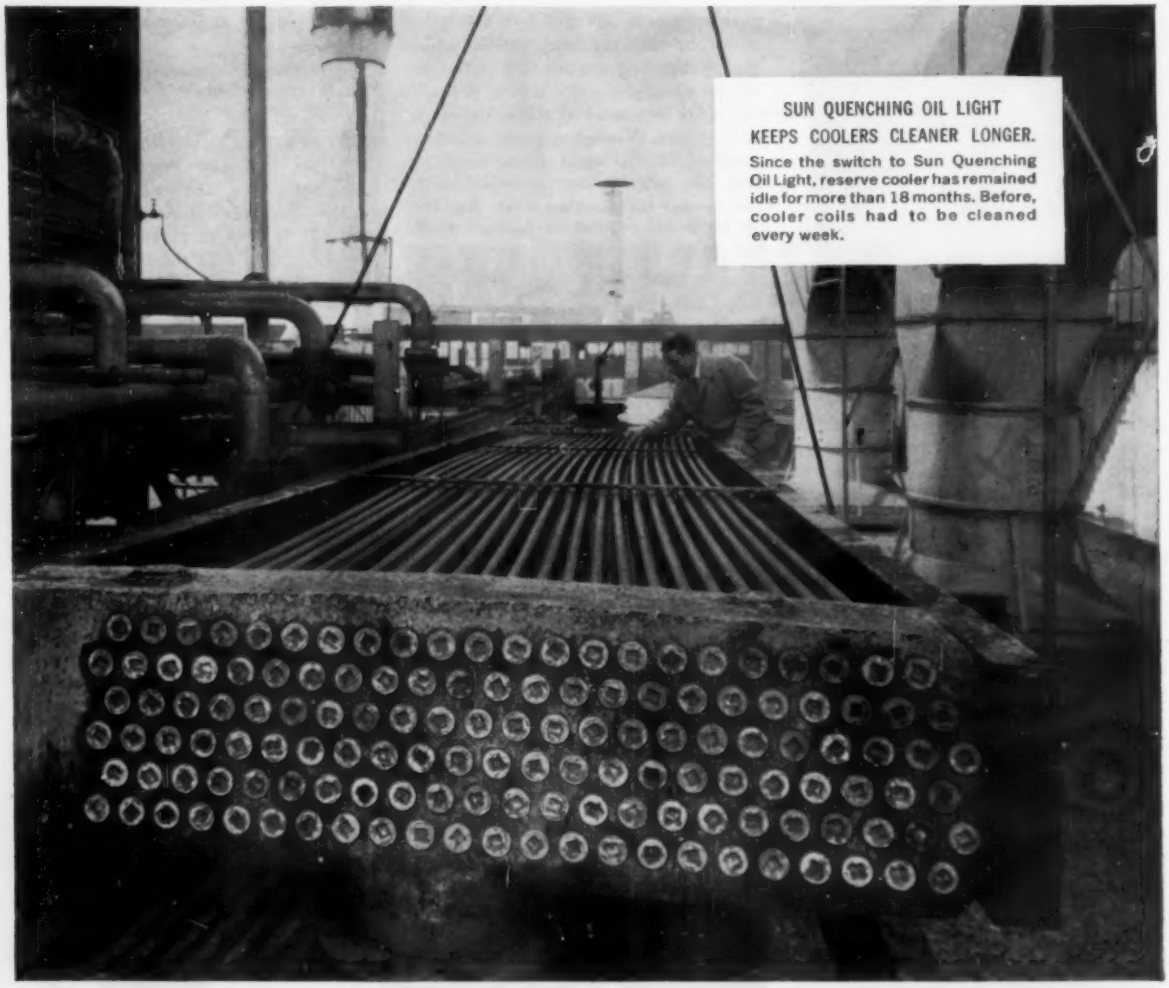
Allied Research Products has announced a new additive for use with Iridite No. 4-73 for polishing die cast zinc. It is used to make all additions to Iridite No. 4-73 solutions, at about one-half the material cost of Iridite. It is available in 135-lb. polyethylene carboys.

For further information circle No. 486 on literature request card, page 48-B.

Welding

A new automatic welding torch and control system for high purity atmosphere welding has been announced by Vacuum Specialties. Designed for thin gage nuclear fuel element welding, both sub-assemblies and finished elements, it is suitable for automatic welding of zirconium, zircalloy, titanium, molybdenum or other reactive metals and their alloys. The torch head is a collet-type water-cooled holder, rack and pinion mounted with adjustable cam follower guides. Two voltage-regulated gear-head motors drive the torch head. Electrode sizes are 0.040 to ¼ in.; maximum current,

Transfer Many Thermocouples
With T-E Quick-Coupling Connectors and Panels
Connector Panels T-E has one for your exact needs. These panels provide flexible, centralized control in transferring any number of thermocouples to indicating, multi-point recording and controlling pyrometers. Ideal for patch panel use, they are available in many compact shapes and sizes — with interchangeable plugs and jacks in I-C, C-C, and C-A. A panel for 48 thermocouples and 16 pyrometers measures only 13¼" x 7⅜". Polarity markings and screw-fastened connections make wiring easy.
Quick-Coupling Connectors These connectors permit fast, easy making and breaking of thermocouple circuits. Durable construction guarantees long, dependable usage. Polarized and mechanically interchangeable, all plugs and jacks are of standard matched thermocouple materials. Spring-loaded contacts with long wiping surfaces provide firm but easily broken connections.
Write for Bulletin 23 —H.
Thermo Electric Co. Inc.
SADDLE BROOK, NEW JERSEY
In Canada — THERMO ELECTRIC (Canada) Ltd., Brampton, Ont.


SUN QUENCHING OIL LIGHT
KEEPS COOLERS CLEANER LONGER.
Since the switch to Sun Quenching Oil Light, reserve cooler has remained idle for more than 18 months. Before, cooler coils had to be cleaned every week.

Cooler maintenance practically eliminated by switch to Sun Quenching Oil Light

A leading automotive manufacturer reports a drastic reduction in his cooler maintenance. No heavy sludge deposit forms in cooler coils, because Sun Quenching Oil Light has natural detergency and solvent action that *keep coolers clean.*

IT'S VERSATILE. Sun Quenching Oil Light can be used in any type of quenching-oil system. It has uniform quenching properties and low drag-out.

IT'S ECONOMICAL. Sun Quenching Oil Light can save you money two ways—in low initial cost and in reduced maintenance.

For full information, call your Sun representative or write to SUN OIL COMPANY, Philadelphia 3, Pa., Dept. MP-8.

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NICKEL AND MANGANESE POWDERS

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PM-66

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PLASTIC METALS

Division

National-U.S. Radiator Corporation

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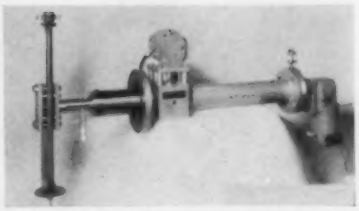
JOHNSTOWN, PA.



600 amp.; maximum rate of vertical travel 60 in. per min.; maximum rate of horizontal travel 32 in. per min.; and horizontal and vertical stroke can be adjusted as required.

For further information circle No. 487 on literature request card, page 48-B.

Cut-Off Machine

Lewis Machine Co. has announced a new machine for the high-speed cutting of commercial welding rod and similar short items. The 4FH will cut 3/32 to ¼ in. mild steel and 3/16 in.

high carbon, alloy and stainless steel. Feed speeds range from 75 to 520 ft. per min. with maximum accuracy in the range of 125 to 395 ft. per min. This new cut-off travels with the rod and cuts while in motion.

For further information circle No. 488 on literature request card, page 48-B.

Creep Testing

A new creep rupture testing machine has been announced by Arcweld Manufacturing Co. The new model M measures 20 by 30 by 78 in. and has a capacity of 6000 lb. A counterbalanced lever system, lever ratio of 16 to 1 and automatic beam leveling device are special features. The counterbalanced furnace can be moved on a

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the most versatile
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ever made!

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guarantees
accurate
on-the-spot
tests!

You save time and money on all Brinell tests with the King Portable. It provides hardness tests on all metals from softest lead to toughest alloys having over 700 BHN.

Uses loads from 62½ Kg. to 3000 Kg.

Keep it in the plant or take it out in the field — can be used in any position anywhere. It's rugged, lightweight and fast!

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KING tester corp.

DEPT. MP-358
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"We get higher recoveries with CHROMTEMP ferrochrome"

Closer chromium control and higher recoveries are obtained by adding CHROMTEMP exothermic ferrochrome to the ladle. Off grade heats are minimized, which means higher plant profits. In addition, this alloy does not preferentially oxidize aluminum added for grain size control. CHROMTEMP ferrochrome is available in three grades which add 5, 8 or 12 points of carbon respectively with each 1% of chromium added. For further information call your ELECTROMET representative.

ELECTRO METALLURGICAL COMPANY, Division of Union Carbide Corporation, 30 East 42nd Street, New York 17, N. Y.

For maximum convenience, CHROMTEMP ferrochrome is packed in cans containing exactly 25 lbs. of chromium.

Electromet
FERRO-ALLOYS AND METALS

UNION CARBIDE

The terms "Chromtemp," "Electromet," and "Union Carbide" are trade-marks of Union Carbide Corporation.

vertical rod. The testing machine permits the use of any type of extension equipment and optical methods of measuring creep extension.

For further information circle No. 489 on literature request card, page 48-B.

Sintering Furnace

A new high production sintering furnace has been announced by Haller, Inc. It is a 75 k.w. continuous belt, globar-type furnace with a 16 ft. belt. Heat is applied in four separately controlled zones. The first zone of 4 ft.

burns out the volatiles and impurities. A second zone, 6 ft. in length, brings the parts up to the sintering temperature. This is called a soaking zone. The third zone of 6½ ft. is the actual sintering zone. The last 4-ft. section is a controlled cooling zone. Endothermic and exothermic atmospheres are used in this furnace plus provisions to introduce natural gas into the prepared atmosphere to create a carburizing atmosphere.

For further information circle No. 490 on literature request card, page 48-B.

Thermowells

A new, expanded line of thermowells, both bar stock and built-up types, has been announced by Thermo Electric Co. Thermowells are available in over 5700 different combinations to satisfy temperature, environmental and installation requirements. Bar stock wells are drilled by the rifle boring process with bore concentricity guaranteed within 10% of wall thickness. They are available flanged, threaded—with hex head or wrench flats—or with ground joints. Built-up wells of seamless pipe are available with threaded mounting bushings or flanges. Each thermowell, both bar stock and built-up, is given an internal hydrostatic test as a final precaution against pressure failure.

For further information circle No. 491 on literature request card, page 48-B.

Barrel Finishing

A new barrel finishing system which cuts time cycles up to 70% and makes it possible to barrel finish inside diameters has been announced by Minnesota Mining & Manufacturing Co. It combines the principles of rotation and vibration for rapid results during cut-down cycles, and is capable of using either principle alone. The machine is 67½ by 50 in. by 8 ft. with

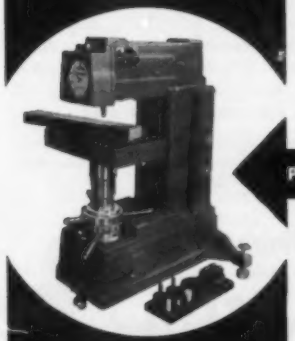
an octagonal barrel. The vibratory barrel will operate at rotating speeds from 4 to 20 rpm. The speed of the vibrator is fixed at 2,300 cycles per min., and both ends of the barrel are synchronized with timing belts so that vibration is uniform throughout the media.

For further information circle No. 492 on literature request card, page 48-B.

Titanium Plate

Light-gage plate of Ti-75A titanium alloy, measuring 75 by 224 in., has

2 Applications (REGULAR AND SUPERFICIAL) 1 Tester



KENTRALL MODEL CT-2

Hundreds of installations over the past few years have proved the economy of the only hardness tester which combines all scales of Rockwell Test (15 to 150 kg. loads).
The Kentrall cuts costs because it does the job of two conventional testers, requires only half the space and maintenance. Write for more detailed information, plus a list of prominent users who have switched to Kentrall. TB148

PRICE $680.

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This booklet has 8 pages of specifications and helpful suggestions on colloidal-graphite products for Aluminum Extrusion, Stainless Steel Forging, Stretch Forming, No-Drip Crane Lubrication, Dry Film Precoating, Titanium and Shell Forging, Die Casting . . . and many others. Ask for "The Biggest Ounce of Protection" and write us for recommendations of the proper dispersions for your operations.

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ACHESON

dispersions digest

Reporting uses for

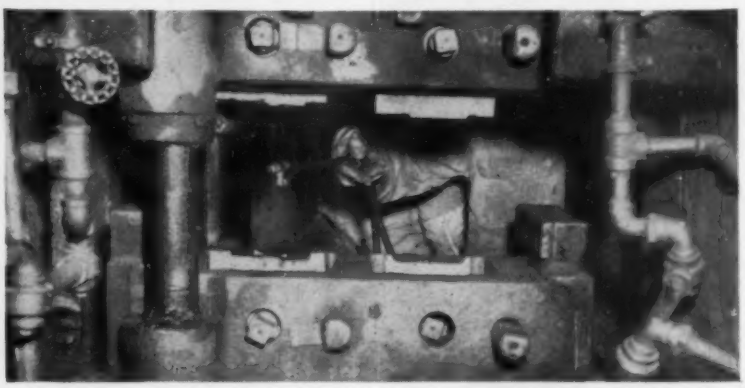
dag® BRAND DISPERSIONS

COLLOIDAL GRAPHITE, MOLYBDENUM DISULFIDE, VERMICULITE, AND OTHER SOLIDS

COLLOIDAL GRAPHITE PROVES IDEAL AS FORGING LUBRICANT

Lubricants to be suitable for use on forging dies for steel and nonferrous metals must be stable under the high temperatures and pressures involved. Besides providing the most effective lubrication for hot-work dies, 'dag' brand dispersions act as coolants. Total advantages gained by using Acheson colloidal graphite, as described in the following applications are: improved quality of the forging, reduced die wear, lower production costs, and improved working conditions.

'dag' dispersion improves quality, cuts costs for Utica Drop Forge and Tool Division. With a large share of their capacity being devoted to the forging of jet engine blades, Utica finds it must maintain high production, consistently high quality, and a competitive price. Blade-forging dies have a comparatively short life due to rapid wear caused by the thinness of the blades, the high pressures required to form the heat-resistant alloys used, and the closer tolerances required. They have found that *every one* of these requirements can be met by using 'dag' colloidal graphite dispersed in water as their forging lubricant. First, it must withstand temperatures which range from 1950-2200° F. Sprayed on both halves of the die it forms a tightly adhering, smooth, microscopically-thin film that aids metal flow and substantially protects the die itself. In many cases, this has meant fewer finishing operations and therefore higher production, due to the improved quality of the blades. A compressor blade formerly required four blows from upset to finish, with an intermediate heat and tumbling operation. Now, this operation is done in only two blows from original heat. The savings . . . $16,000 a year on this part alone! Add increased life of these precision dies and you can appreciate what a 'dag' colloidal graphite dispersion means to efficient forging. Utica finds water-based dispersions best for press forging, and colloidal graphite in oil the best lubricant for hammers.



Operator spraying colloidal graphite on both top and bottom die halves before forging jet engine blades at Utica Drop Forge and Tool Division. Kelsey-Hayes Company.

Concentrated Acheson colloidal graphite being applied to die surfaces before they are put in service.

Pre-treatment and operational use of 'Aquadag' greatly increases die life. Before putting dies into service, a prominent midwestern manufacturer finds that by preheating them to about 250° F. and brushing on a dispersion of colloidal graphite in water, they have generally *doubled* the working life of their dies. When used as an operational lubricant, actual measurements of wear on a die for a truck body brace were only *one-third* the former rate. And this was with 'Aquadag' diluted 1 to 240 in water! . . . Ample proof of the wide coverage, film toughness, lubricity, and basic economy of a 'dag' brand dispersion.

Colloidal graphite is resistant to heat, does not react with the die steel, and the extremely small particle size permits an actual adsorption to the metal surface. A water carrier eliminates the usual smoke and fumes thus affording better working conditions and keeping die temperatures down. After the carrier evaporates, a dry graphite film remains which, besides being an efficient lubricant, protects the die from the accumulation of abrasive dust and scale. Die life is extended from 8 to 14 days and production increased by the reduction in downtime.

Specially compounded, ready-to-use forging lubricants containing 'dag' colloidal graphite are available from industrial lubricant suppliers. If you have a forging lubrication problem, it may pay you to call in your Acheson Service Engineer.

Write for additional information contained in Acheson Bulletin No. 426. Address Dept. MP-28.

ACHESON *Colloids Company*

PORT HURON, MICHIGAN

A division of Acheson Industries, Inc.

Also Acheson Industries (Europe) Ltd. and affiliates, London, England

50

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been announced by Titanium Metals Corp. Nominal thickness is 3/16 in. The large plate was produced for chemical process engineers, seeking information on large-size plate for reactor vessels handling corrosive materials.

For further information circle No. 493 on literature request card, page 48-B.

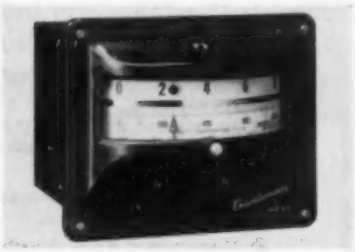
Clad-Steel Pipe

A new corrosion-resistant pipe made of clad steel in diameters down to 4 in. has been announced by the Lukens Steel Co. The inside surface is a layer of solid stainless steel, bonded to a heavier outer layer of carbon steel. It is recommended for chemical, petroleum and nuclear industries.

For further information circle No. 494 on literature request card, page 48-B.

Pyrometers

New model pyrometers have been announced by West Instrument Corp. A diecast aluminum meter and a set-



ting knob with a guard to preserve precise setting are new features.

For further information circle No. 495 on literature request card, page 48-B.

Ferro-Columbium

A new grade of ferro columbium has been announced by Shieldalloy Corp. It has a columbium-to-tantalum ratio of about 40 to 1. The 0.8% tantalum content will result in columbium-containing cast and wrought stainless parts with less than 0.10% tantalum. The following percentages of other elements are present: columbium, 65%, silicon 0.10%, and carbon 0.02%.

For further information circle No. 496 on literature request card, page 48-B.

Freezer

Alpha Electric Refrigeration Co. has announced new low temperature freezers with ranges of −120 to +300° F. These new standard units occupy 34 by 28 by 38 in. of space. The automatic controls, provided with

the standard units, indicate plus or minus from −120 to +150° F. Other controls are available for higher temperatures. Units can be modified to

TESTING MAGNETIC CHUCK EFFICIENCY?

...just one of many uses for DILLON FORCE GAUGE

No matter how varied your testing problems, chances are you can solve them better, quicker and more accurately with a compact Dillon Force Gauge. In this application, a Walker Magnetic Chuck is being tested for holding power. The load is applied by means of a hand wheel which works in conjunction with the Gauge. As the pressure approaches the maximum point, the plate on the chuck will slip, causing the indicator to move back.

This is but one of hundreds of tests in which Dillon Force Gauges are used daily to assure safety to worker and equipment alike. Available in 12 capacities from 0-10 to 0-50,000 lbs., these versatile instruments precisely measure pressure, tensile or torque in even the most limited area. Overload protected and individually calibrated, lightweight Dillon Force Gauges can be used alone or incorporated into special testing devices. Max. pointer available. Write today for free price list and profusely illustrated brochure showing many other applications.

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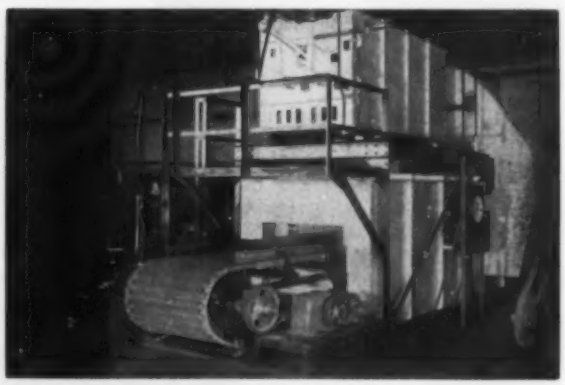

carl mayer Hi-Temp, Recirculating Type HEAT TREAT FURNACES

effect large savings in drawing, tempering, ageing, and heat treating of such products as bearings, billets, springs, screws, tools, gears, etc. in steel or aluminum. Continuous operation at temperatures up to 1200° F. Temperature uniformity guaranteed! Gas, oil, or electric fired.

Write for Bulletin HT-53

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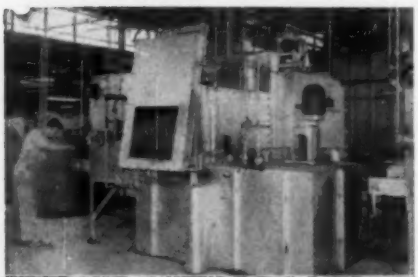
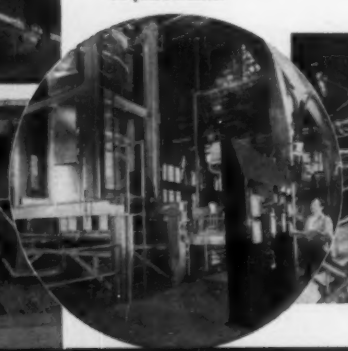
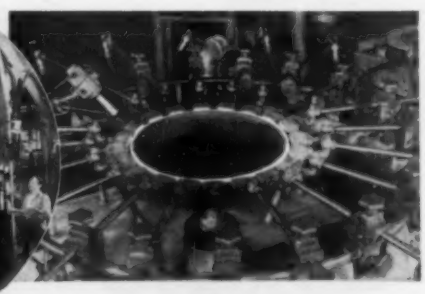
OTHER PRODUCTS: Core & Mold Ovens • Rod Bakers • Paint and Ceramic Drying Ovens • Special Processing Equipment & Accessories

"Do-It-Yourself" can sometimes be costly

Buying equipment and supplies to perform heat treating operations within your own plant is only one step in many that must be considered when contemplating the installation or expansion of a heat treating department.







Here are some of the factors that should be included when figuring the cost of operating your own heat treating department—of "doing-it-yourself" when it comes to heat treating:

- **Technical skill:** Trained operators whose skill is the result of years of experience are essential
- **Maintenance:** Rapid deterioration of equipment occurs unless there is constant repair, maintenance, and skillful handling of the equipment
- **Quality control:** Testing equipment and skilled operators are necessary to maintain uniformity and quality control of all heat treating operations
- **Sufficient equipment and supplies:** A great variety of equipment is needed to meet the requirements of annealing, brazing, hardening, carburizing, stress relieving, nitriding, and all other heat treating processes; and an endless variety of materials and supplies must be kept on hand.

These problems and many more have been solved by commercial heat treaters. They have the answers because heat treating is their business.

Every MTI commercial heat treater listed here is a specialist with complete service facilities under one roof. Each one has the facilities, equipment, skill and experience which will enable him to meet your most exacting heat treating requirements.

American Metal Treatment Co.
Elizabeth, New Jersey
Anderson Steel Treating Co.
Detroit, Michigan
Benedict-Miller, Inc.
Lyndhurst, New Jersey
Bennett Heat Treating Co., Inc.
Newark 3, New Jersey
Commercial Metal Treating, Inc.
Bridgeport, Connecticut
Cook Heat Treating Co. of Texas
Houston 11, Texas
The Dayton Forging & Heat Treating Co.
Dayton 3, Ohio
Dominy Heat Treating Corp.
Dallas, Texas
Drever Company
Philadelphia 33, Pennsylvania
Greenman Steel Treating Company
Worcester 5, Massachusetts
Fred Heinzelman & Sons
New York 12, New York

MTI
MALLEABLE ENGINEERING
METAL TREATING INSTITUTE

Alfred Heller Heat Treating Co.
New York 38, New York
Hollywood Heat Treating Co.
Los Angeles 38, California
Ipsenlab of Canada, Ltd.
Toronto, Ontario, Canada
Ipsenlab of Rockford, Inc.
Rockford, Illinois
L-R Heat Treating Company
Newark, New Jersey
The Lakeside Steel Improvement Co.
Cleveland 14, Ohio
Metallurgical, Inc.
Minneapolis 14, Minnesota
Metallurgical, Inc.
Kansas City 8, Missouri

New England Metallurgical Corp.
South Boston 27, Massachusetts
Owego Heat Treat, Inc.
Apalachin, New York
Paulo Products Company
St. Louis 10, Missouri
Pittsburgh Commercial Heat Treating Co.
Pittsburgh 1, Pennsylvania
Pittsburgh Metal Processing Co., Inc.
Pittsburgh 15, Pennsylvania
The Queen City Steel Treating Co.
Cincinnati 25, Ohio
J. W. Rex Company
Lansdale, Pennsylvania
Stanley P. Rockwell Company
Hartford 12, Connecticut
Scott & Son, Inc.
Rock Island, Illinois
Syracuse Heat Treating Corp.
Syracuse, New York
Temperature Processing Co.
North Arlington, New Jersey

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to recognize

superior quality

brass and aluminum

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bring out the ***BEST*** *in your fabricated products*

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This means that you can maintain maximum machine speeds with assured high standards of precision and product finish . . . with fewer rejects . . . and with excellent tool life.

Always specify SCOVILL HIGH SPEED BRASS ROD (free-cutting). . .

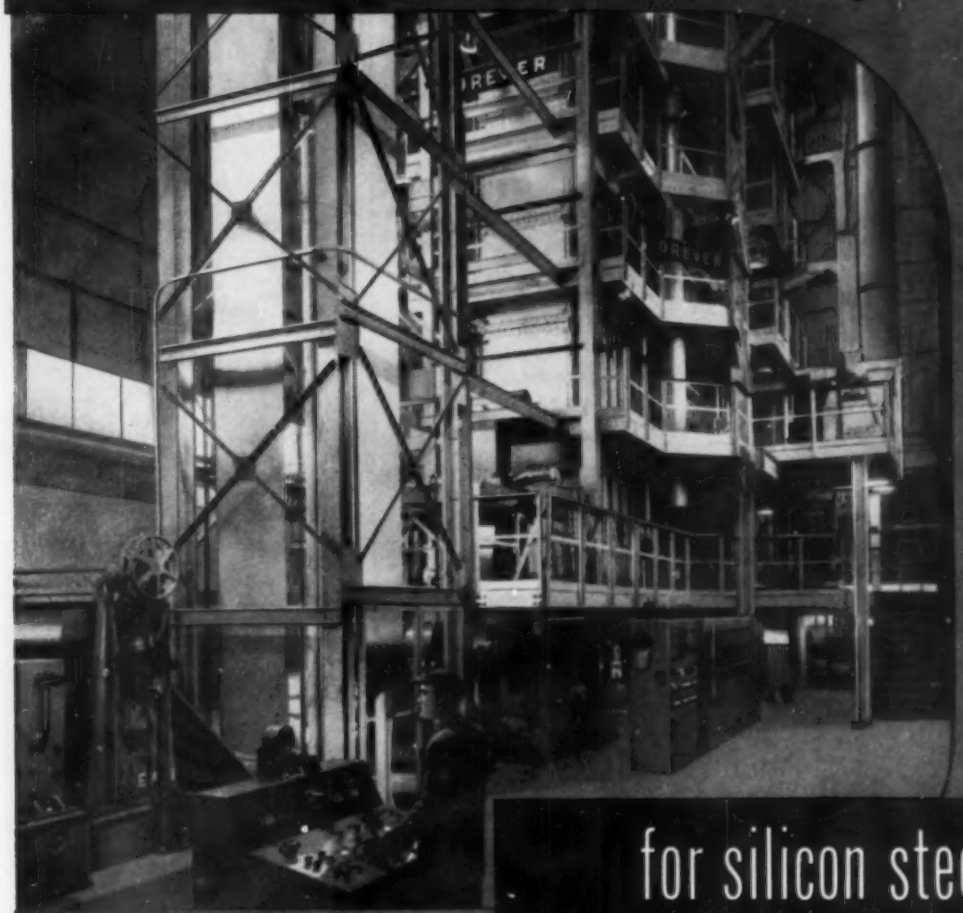
to bring out the BEST in your fabricated products

Scovill Manufacturing Company, Mill Products Division, 99 Mill Street, Waterbury 20, Connecticut. Phone Plaza 4-1171.

199C17

DREVER

Continuous Strip Annealing Furnace Line



for silicon steel

Delivery end of Drever gas-fired radiant tube heated vertical annealing furnace for silicon steel strip installed at Empire Steel Corporation, Mansfield, Ohio.

This furnace was designed and installed by the Drever Company to produce 8 tons per hour of silicon steel strip. The heating and soaking zones are gas-fired radiant tube heated, the tubes having a connected load of 13,500 CFH of natural gas.

The furnace has been engineered to handle silicon steel strip in thicknesses from 0.017" to 0.025", in widths from 24" to 42", and for speeds from 60 to 180 FPM.

Drever continuous annealing lines for Tin Plate, Galvanized Stock, other Low Carbon Steel and Non-Ferrous Strip in capacities up to 30 tons per hour, provide an economical investment in tonnage production of quality material.

DREVER COMPANY

Red Lion Rd. & Philmont Ave.

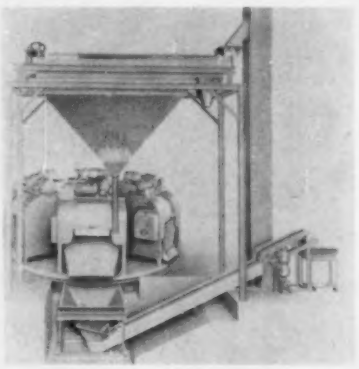
BETHAYRES, PA.

provide viewing windows, casters and other recording or indicating instruments.

For further information circle No. 497 on literature request card, page 48-B.

Barrel Finishing

A 6-station automatic barrel finishing system, mounted on a turntable and equipped with a memory device, has been announced by Almco, Queen Products. It automatically rotates completed work to a single operator station for unloading and reloading. As the operator loads each barrel, he



sets its timer for a prescribed processing cycle. The timed-out barrel is rotated to his station when the work has been completed. Each barrel is individually timed and the new system will simultaneously deburr and finish parts requiring time cycles from 15 min. to 50 hr.

For further information circle No. 498 on literature request card, page 48-B.

Shell Core Blower

Harrison Machine Co. has announced a low pressure (10 to 25 lb.) shell core blower for the small foundry. It is a manually operated, 2-station shuttle-type machine which permits the making of a variety of

cores on each end. Each station accommodates core boxes up to 4⅛ by 10 by 15 in. The feeder has a capacity of 200 lb. of phenolic resin coated sand. Each station has roll-over action, center pivoted.

For further information circle No. 499 on literature request card, page 48-B.

PROBLEM WELDING?

Use P&H Low-Hydrogen Electrodes

P&H Low-Hydrogen electrodes give you industry's widest choice of alloys for welding "difficult" steels. There's a chemical analysis to match most parent metals.

Welds are of X-ray quality, with greater ductility at high tensile strength, and better impact properties. For more detailed information, write for Bulletin R-29, Dept. 301E, Harnischfeger Corp., Milwaukee 46, Wisconsin.

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P&H WELDERS • ELECTRODES POSITIONERS

MISCO
Specialists IN NICKEL-BEARING ALLOY FABRICATION

Heat and Corrosion Equipment

Processing Equipment

Specialized HEAT-RESISTING ALLOY
• Design
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BASKETS • TRAYS
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BOXES • MUFFLES
FIXTURES

Specify MISCO DESIGN and FABRICATION
IT COSTS NO MORE!

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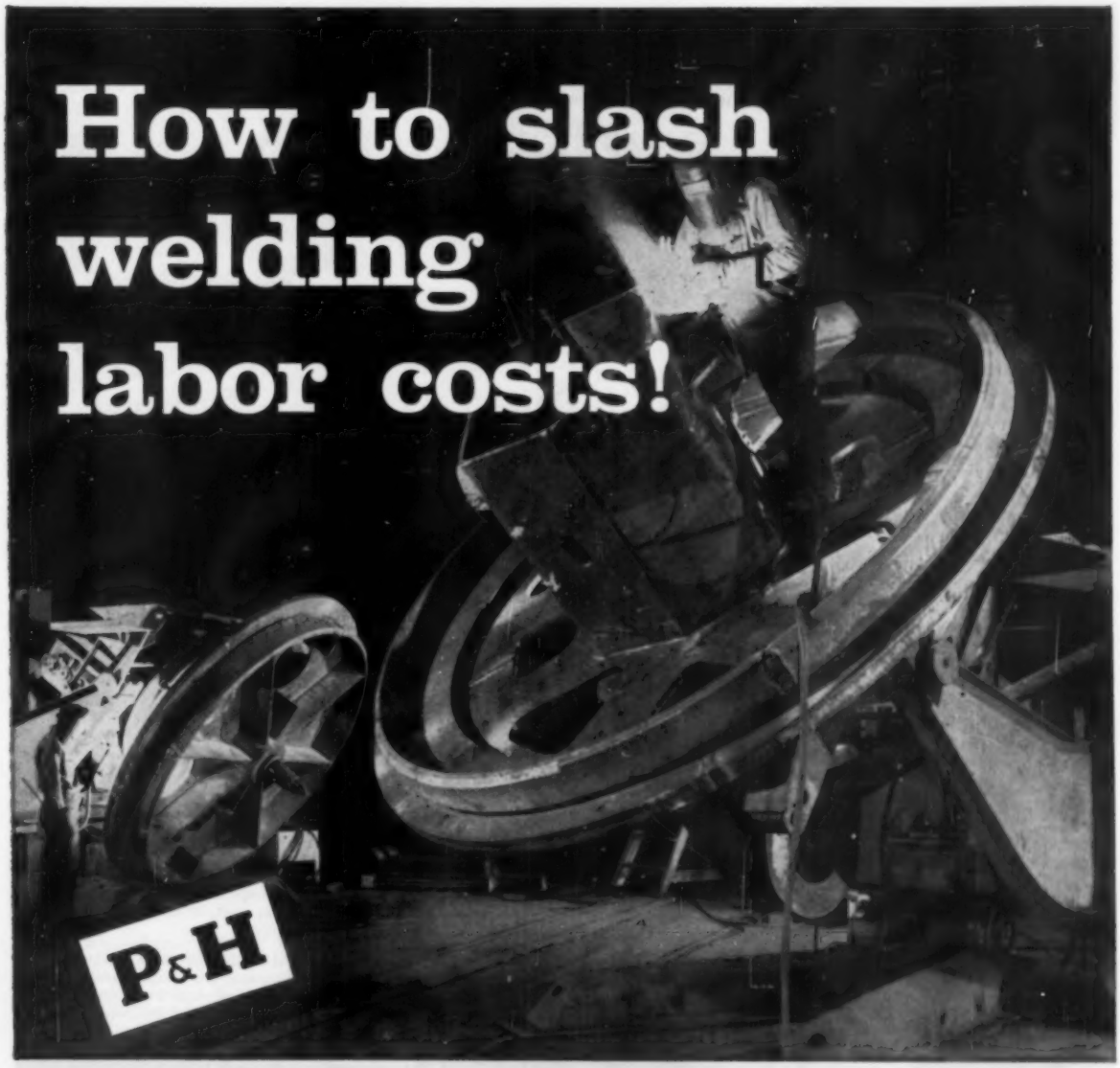

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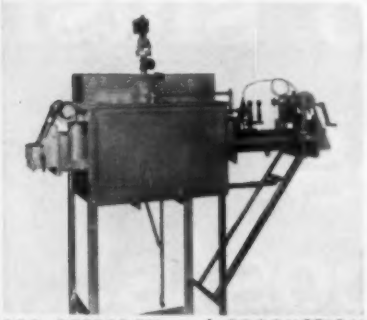

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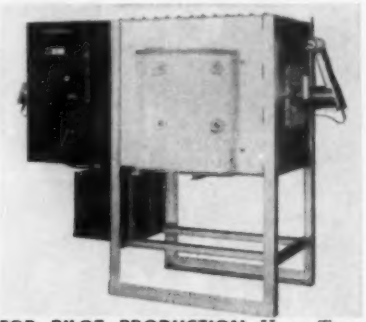

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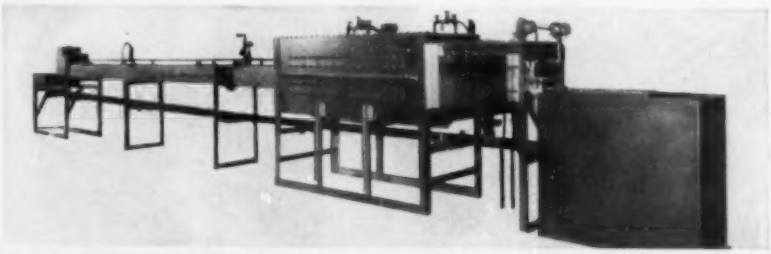

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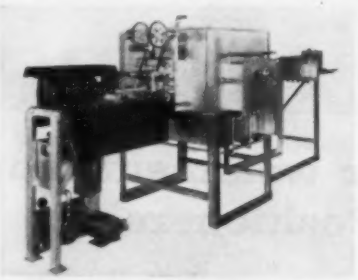

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Catalog of stock extrusion dies. *Jarl Extrusions*

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Bulletin on new invisible finish for aluminum describes Alodine No. 1000 and includes flow sheet for immersion process. *American Chemical Paint*

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Booklets on "Applications of Dissociated Ammonia", "Ammonia Installations for Metal Treating", "Nitriding Process", "Carbonitriding". *Armour*

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Brazing News No. 78 tells of silver brazing's characteristics. Case histories. *Handy & Harman*

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New Bulletin 109 on combination gas and oil burners. Description and output data. *Thermal Research & Engineering*

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15 data sheets on Carmet carbide grades. Typical applications, analysis, physical characteristics and grain structure. *Allegheny Ludlum Steel Corp.*

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76-page catalog 56-G of sintered carbides, hot pressed carbides, cutting tools, drawing dies, wear resistant parts. *Metal Carbides*

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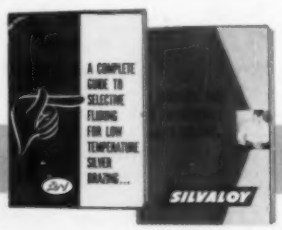

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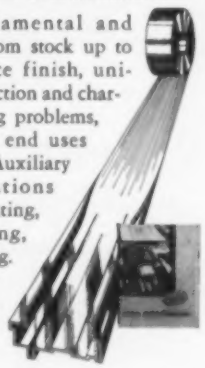

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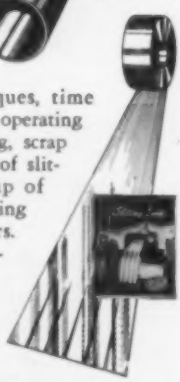

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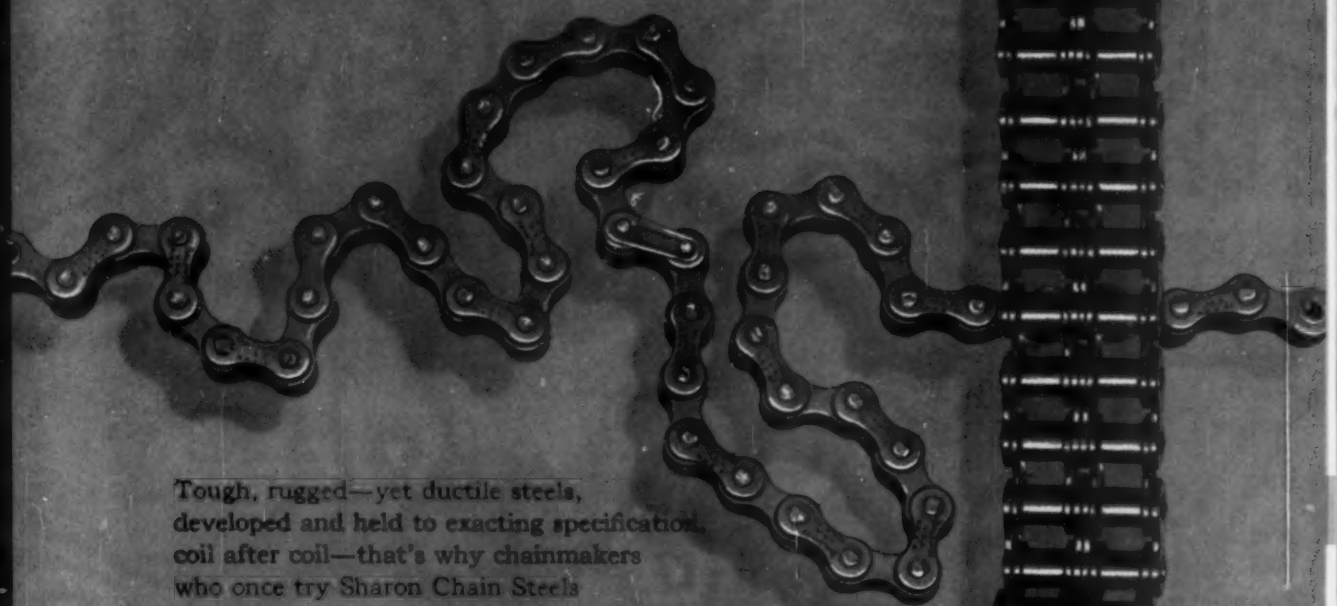

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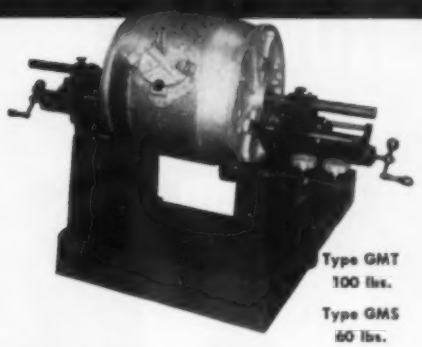

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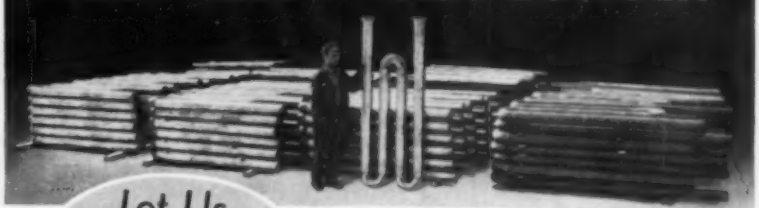

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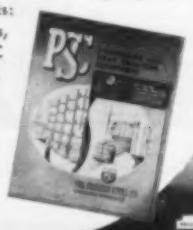

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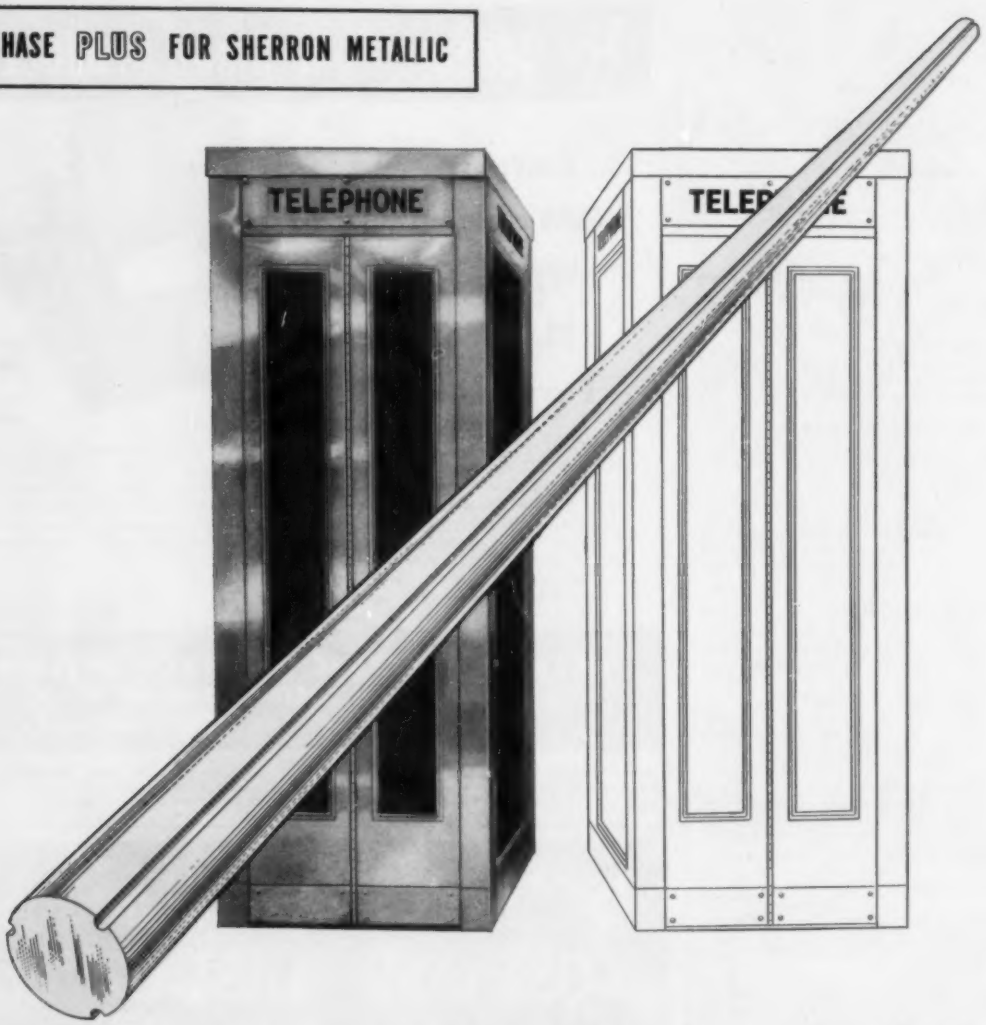

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Precision Tubing consistently is unequalled and unsurpassed in comparative quality tests of accuracy, temper, straightness and roundness. With Precision you are always sure of extra quality at no extra cost—sells at regular mill prices. Available in sizes from .010" to 1.000" O.D. in copper, brass, aluminum, nickel and nickel alloys, Ni-Span "C", phosphor bronze and nickel silver. Accurately drawn seamless capillary tubing in straight random lengths or coils.

Write for folder "Small Tubing For Industry" to Dept. 3A, Precision Tube Co., North Wales, Penna.

PRECISION TUBE COMPANY

573. Hardness Tester
Data on portable hardness tester with Rockwell and Brinell scales. *Mechanical Devices*

574. Hardness Tester
4-page bulletin on portable metal hardness tester for any shape or metal. Ranges, features. *Newage Industries*

575. Hardness Tester
Catalog 72-1 on Leitz miniload tester for Vickers and Knoop hardness tests. *Opto-Metric Tools, Inc.*

576. Hardness Tester
13-page booklet on microhardness tester with optional Vickers or Knoop diamond. *Geo. Scherr*

577. Hardness Tester
Data on hardness testing scleroscope with equivalent Brinell and Rockwell C numbers. *Shore Instrument*

578. Hardness Testers
4-page bulletin on hardness tester for regular and superficial Rockwell tests. Special features and accessories. *Torsion Balance*

579. Heat Treat Pots
Catalog on pressed steel pots for lead, salt, cyanide, oil tempering and metal melting. *Eclipse Industrial Combustion Div.*

580. Heat Treating
Loose leaf data sheets on heat treating oils, salts, carburizing compounds. *Park Chemical*

581. Heat Treating Belts
Catalog of conveyor belts and data for their design, application and selection. *Ashworth Bros.*

582. Heat Treating Fixtures
4-page folder on retorts, baskets, trays, carburizing boxes, fans for heat treating. *Aluminum & Architectural Metals*

583. Heat Treating Fixtures
Folder on carburizing boxes, trays, heat treat fixtures and baskets. *Misco*

584. Heat Treating Fixtures
24-page catalog on heat and corrosion-resistant equipment for heat treating and chemical processing. 30 classifications of equipment. *Pressed Steel*

585. Heat Treating Fixtures
New 32-page catalog G-10A lists process equipment, heavy welded fabrications, muffles, trays, fixtures for furnaces, heat-treating equipment, pickling equipment. *Rolock*

586. Heat Treating Furnaces
12-page booklet on various heat treating furnaces contains chronology of advances. *Holcroft*

587. Heat Treating Furnaces
Folder on industrial furnaces. Continuous designs. Insulation. *Pacific Industrial*

588. Heat Treatment
Bulletin 200 on car hearth, rotary hearth, belt, chain, pusher, and "hi-head" furpit, roller hearth, belt, chain, pusher, and "hi-head" furnaces. *R-S Furnace*

589. Heaters
Bulletin on immersion heaters for electroplating solutions. *Glo-Quartz*

590. Heaters
16-page publication GEA-5866 gives case histories of use of tubular heaters in shrinking machinery, extruding machines, radiant ovens and paint heaters. *General Electric*

591. High-Strength Bronze
12-page booklet on telnic bronze with high strength, high hardness, good machinability, age hardenability, corrosion resistance. *Chase Brass*

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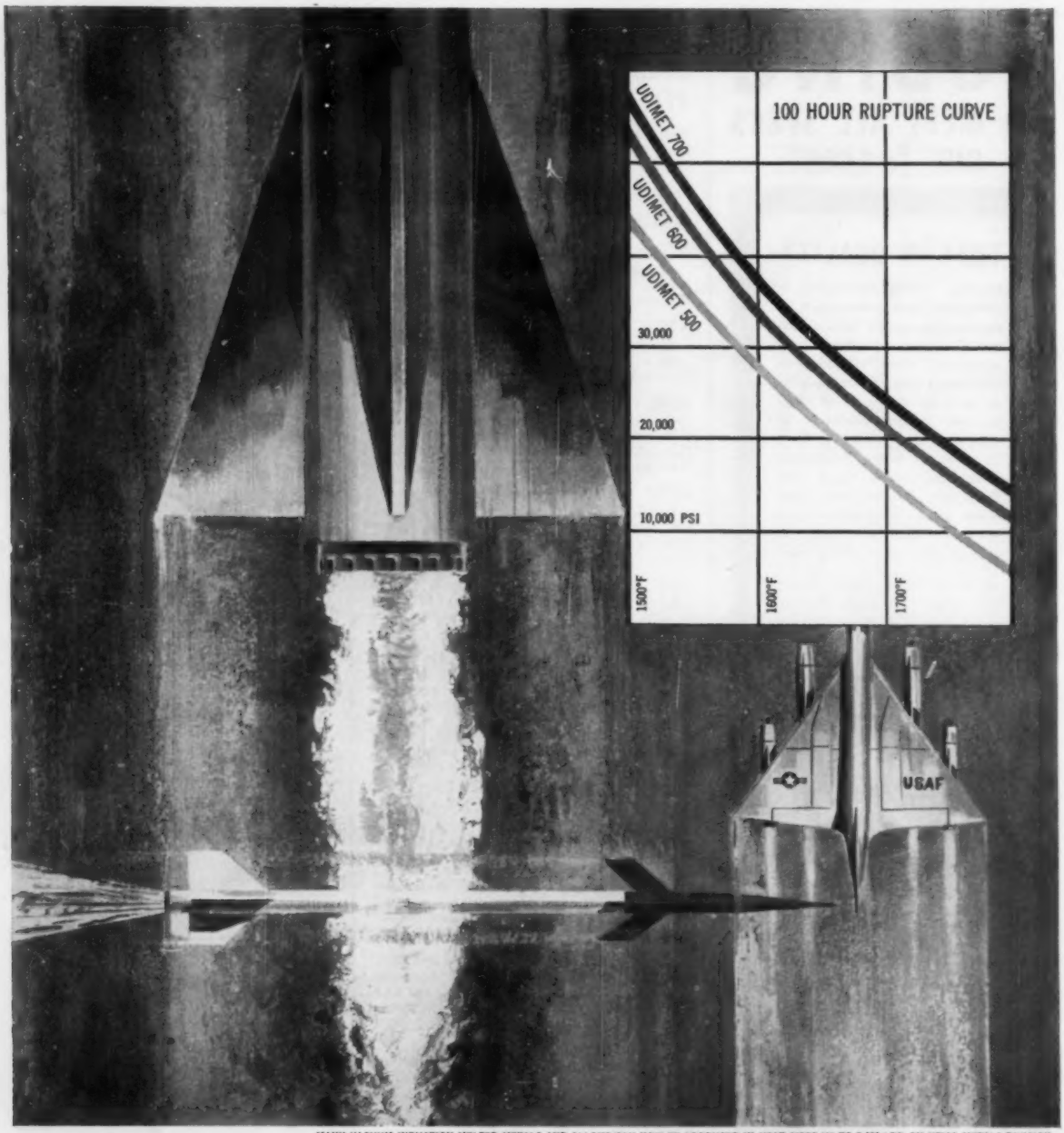

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592. High-Strength Steel
48-page book on T-1 steel, its properties and applications. *U.S. Steel*

593. High-Temperature Alloy
Property data for 21% Cr, 9% Ni heat-resistant alloy. *Electro-Alloys*

594. High-Temperature Alloy
Bulletin 106 gives data on Type 321 stainless and contains temperature range chart for six alloys. *Rolled Alloys*

595. High-Temperature Alloy
14-page bulletin on Udimet 500 gives composition, heat treatment, machinability, hot working characteristics and properties. *Utica Metals Div.*

596. High-Temperature Alloys
"Haynes Alloys for High-Temperature Service" summarizes all available data on 10 superalloys and lists physical and mechanical properties of two newly developed alloys. *Haynes Stellite*

597. Indicators
Data sheet ND46-33 (23) on electronic potentiometer instruments for temperature indication. *Leeds & Northrup*

598. Induction Brazing
Folder tells how tips of carbide may be brazed on tool shanks. *Ohio Crankshaft*

599. Induction Furnace
4-page folder on combination induction melting and holding furnace and automatic pouring unit. *Ajax Engineering*

600. Induction Heating
Need for ground detectors on high frequency induction furnaces discussed in Inducto Metal Melting Newsletter, No. 5. *Inductotherm*

601. Inspection
New Bulletin 90 on nondestructive testing of ferromagnetic wire rope. Equipment and how it is used. *Magnetic Analysis*

602. Inspection
New 16-page catalog on illuminated Borescopes for industrial inspection of deep recessed areas. *National Electric Instrument Div.*

603. Laboratory Furnace
Data sheet on laboratory vacuum melting furnace describes basic unit, vacuum chamber, vacuum pumping system. *High Vacuum Equipment Corp.*

604. Laboratory Furnaces
Folder describes and illustrates tubular furnace for use in tensile testing, and control panels. *Marshall Products*

605. Laboratory Supplies
Instruments and apparatus for control, research, development laboratories. *Harshaw Scientific*

606. Leaded Steels
16-page booklet on basic characteristics, mechanical properties and workability of leaded steels. Case histories. *Copperweld Steel Co.*

607. Lithium
New 24-page booklet on lithium, cesium and rubidium. Principal uses. Charts and tables. *Montgary Explorations, Ltd.*

608. Low-Temperature Alloys
New bulletin on some properties of nickel alloys at low temperatures. Wrought and cast alloys. *International Nickel Co.*

609. Lubricant
Bulletin 425 on colloidal dispersions for use in metal casting. Best formulas for achieving high lubricity and wetting action. *Acheson Colloids*

(*Continued on page 48A*)

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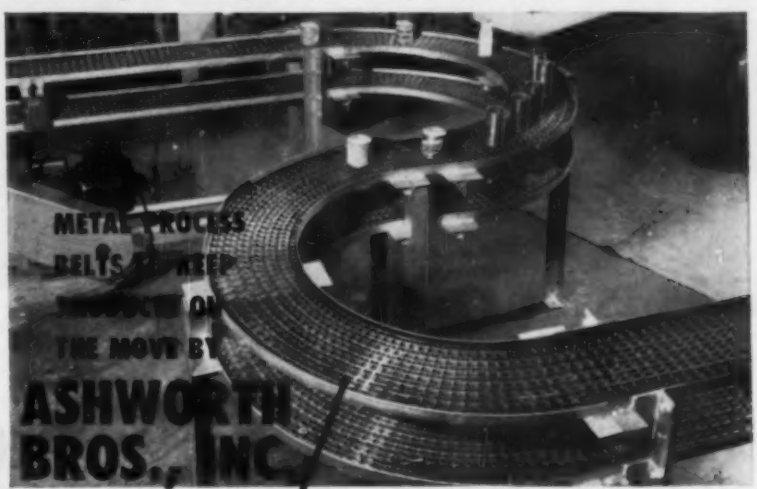

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Illustrated literature available, specify catalog M12.

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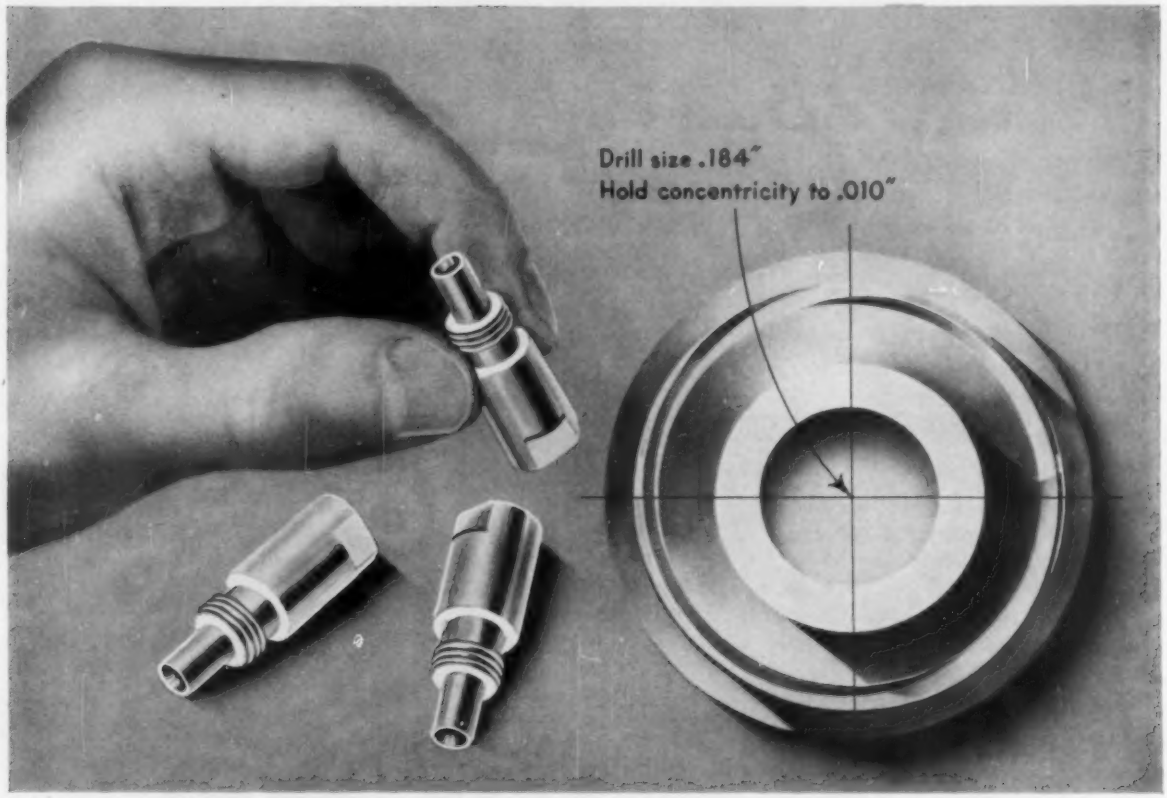

THE broad line of Anaconda free-cutting copper and copper-alloy rods gives you widest latitude in selecting from warehouse stock the precise rod for most screw machine jobs. But every once in a while there are special requirements.

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Your requirements: Anaconda Rods are consistently uniform in composition, temper, and free-cutting characteristics. Consequently, they make possible easy duplication of cutting speeds and feeds known to be satisfactory from previous job records.

When you need special physical characteristics, such as a harder core for deep drilling or additional ductility to permit spinning or cold forming after machining, either the temper, the alloy, or both can be adjusted to meet your requirements.

Free technical service: It is the function of the Technical Department of The American Brass Company to assist metal users in the solution of special problems. This service is at your disposal without charge.

Comprehensive data on composition and machinability of standard Anaconda Alloys, standard specifications, weights, and dimensions of standard rods is available in Publication B-3. For this booklet – for special technical assistance – write: The American Brass Company, Waterbury 20, Conn. In Canada: Anaconda American Brass Ltd., New Toronto, Ont. 8778

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New Bulletin on

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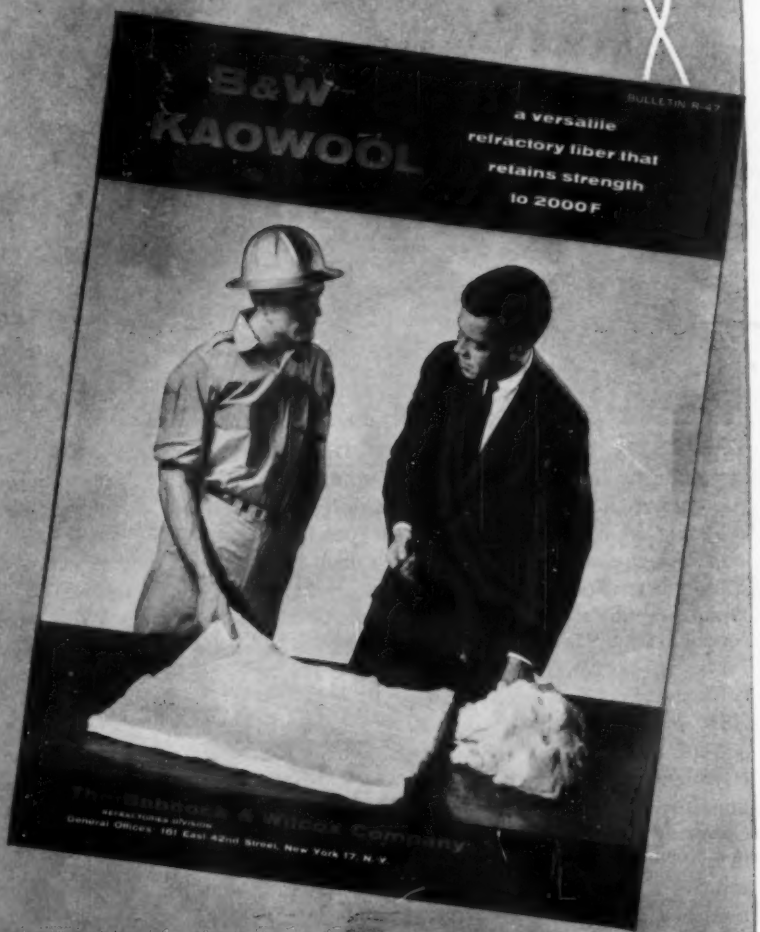
Gives data on many uses of 2000 F refractory ceramic fiber

B&W Kaowool, the 2000 F refractory fiber, is being successfully used for expansion joints in walls, roofs, around burners and in car tops of ferrous and non-ferrous heating furnaces. B&W Kaowool blankets are also serving as insulation in the pre-heating and stress relieving of large welded units. Write for new bulletin giving helpful data on B&W Kaowool, the multi-purpose ceramic fiber that withstands high temperature service.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(Continued from page 45)

610. Lubricant
New 4-page Data Sheet No. 2049 on solid film lubricant. *Electrofilm*

611. Magnesium
42-page booklet on wrought forms of magnesium. Includes 31 tables. *White Metal Rolling & Stamping*

612. Manganese
9-page article on electromanganese. Manufacturing procedures, product characteristics, uses. In Foote Prints. V. 28, No. 2. *Foote Mineral Co.*

613. Marking
Data on hammers for metal markings. *Pannier Corp.*

614. Marking Machines
Data on various types of marking machines. *Jas. H. Matthews & Co.*

615. Marking Metal
Bulletin on electromark process. Equipment. Operating instructions. *Electromark*

616. Melting
8-page booklet gives suggestions on how to operate a melting furnace. *Campbell-Hausfeld*

617. Melting Furnace
Bulletin gives specifications, diagrams, performance and other technical data on Simplex melting furnaces. *Lindberg*

618. Melting Furnaces
New Catalog C5A gives applications and specifications of 10 different types of melters — soft metal, brass, aluminum, crucible type and others. *American Gas Furnace Co.*

619. Metal Powders
16-page booklet on CDF iron powder. Briquetting characteristics, green strengths, iron sinters, iron-copper mixes, iron-copper bushings and iron-copper-carbon mixes. *Republic Steel*

620. Metal Treatment
Booklet on metal treating and finishing products. *John Swift Chemical Co.*

621. Microhardness Tester
Bulletin describes the Kentron microhardness tester. *Torsion Balance*

622. Microscope
New brochure SB56 on cycloptic stereoscopic microscope. *American Optical*

623. Microscopes
22-page catalog describes microscopes featuring ball bearings and rollers throughout the focusing system and a low-position fine adjustment. *Bausch & Lomb*

624. Microscopes
40-page catalog on metallographs, metallurgical, toolmakers, stereoscopic, polarizing, phase and other microscopes. *Unitron Instrument Div., United Scientific*

625. Nickel Plating
16-page bulletin gives instructions for plating by the sulfamate nickel process. *Hanson-Van Winkle-Munning*

626. Nonferrous Melting
Bulletin 26-A on high frequency furnaces for melting copper, silver, gold, platinum, aluminum and magnesium. *Ajax Electrothermic*

627. Oil Quenching
8-page brochure tells in detail how carbon steel often can replace alloy steel when additive is used in the quenching oil. *Aldridge Industrial Oils*

628. Oil Quenching
Catalog FB-1052-A on self-contained oil cooling equipment. Selection tables for volume of oil required and oil recirculation rates. *Bell & Gossett*

629. Openhearths
12-page booklet shows how openhearths are built. Furnace binding, refractories, combustion and controls, and mechanical equipment. *Loftus Engineering*

630. Ovens
16-page bulletin No. 53 on various types of core and mold ovens, special ovens and heat treating furnaces. *Carl-Mayer*

631. Ovens
New bulletin on truck loaded-type production ovens. Engineering, construction and control features. *Despatch Oven*

632. Ovens
16-page Bulletin 157 on ovens for baking, drying, curing and heat treating. Batch and conveyor types. Air recirculating and heating systems. *Young Bros.*

633. Phosphor Bronze
4-page technical bulletin T-4 on advantages and fabrication of fine-grain phosphor bronze. *Riverside-Alloy Metal*

634. Pickling Baskets
12-page bulletin on mechanical picklers, crates, baskets, chain and accessories. *Youngstown Welding & Eng'g.*

635. Plating
New 8-page brochure on test equipment for plating baths. Controls, anodes, cathodes, agitators, rectifiers described. *R. O. Hull & Co.*

636. Powder Metallurgy
Technical literature on high-density sintered metal parts. *Supermet Div.*

637. Powder Metallurgy
16-page booklet on advantages and disadvantages of process, design data, materials used. *Reese Metal Products*

638. Powder Press
Dorst automatic press for powdered metal is described in bulletin. Pressure ram stroke and other specifications. *Dorst Div., Arnhold Ceramics*

639. Precision Casting
8-page bulletin on investment castings of various ferrous and nonferrous alloys. *Engineered Precision Casting*

640. Protective Coatings
Folder 301 on industrial protective coatings of rubber, neoprene and other materials. *Arco Steel Fabricators*

641. Pyrometer
Catalog No. 100 on radiation pyrometers with ranges from 1000 to 3400°F. *Pyrometer Instrument Co.*

642. Quench Agitation
Information on mixers and agitators, including units applicable to industrial quenching equipment. *Mixing Equipment*

643. Quenching
16-page booklet on modified and full marquenching procedures. Hardness and dimensional control data, cooling curves, case histories. *Sinclair Refining Co.*

644. Radiography
16-page booklet on materials and accessories for industrial radiography. Guide to selection of film. Recommended development techniques. *Eastman Kodak, X-Ray Div.*

645. Radiography
20-page bulletin on gamma radiography. Uses, sources, equipment. *Nuclear Systems Div., Budd Co.*

646. Recirculating Furnace
Bulletin on continuous-type recirculating furnace shows design of furnace, its operation and advantages. *Industrial Heating Equipment Co.*

647. Refractory Coating
Data on aluminum oxide and silicon carbide coating which may be sprayed on. *Norton Co.*

648. Resistance Welding
24-page catalog on equipment for resistance welding includes reference tables and property and application charts. *Ampco*

649. Salt Bath Furnaces
Data on salt bath furnaces for batch and conveyorized work. *Upton*

650. Salt Baths
Reprints 161 and 162 on new advances

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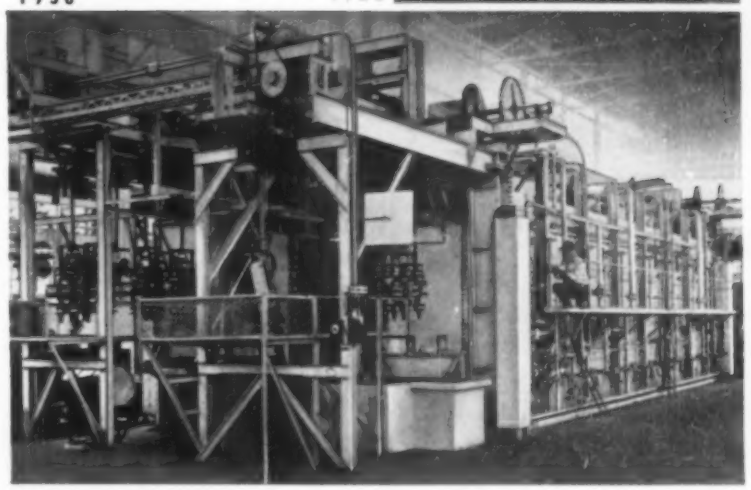

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RESTRICTED SPECIFICATION COLD ROLLED STRIP STEEL

for Spring Steel Requirements such as these...

FORMED PARTS FOR HEAT TREATMENT

SIZE	8 x .036
ANALYSIS	1050
FINISH	Bright
HARDNESS	Rockwell B-78 Max.
THICKNESS TOLERANCE	± .0003 incl. crown
WIDTH TOLERANCE	± .005
MICROSTRUCTURE	Uniform spheroids
COIL SIZE	16" I.D. coils large as possible
PACKAGING	On skids — shrouded

FLAT PARTS FOR HIGH STRENGTH WITHOUT HEAT TREATMENT

SIZE	10 x .020
ANALYSIS	1075
FINISH	Bright
HARDNESS	Rockwell C-30 Min.
THICKNESS TOLERANCE	± .001 incl. crown
WIDTH TOLERANCE	± .005
MICROSTRUCTURE	Small-fine carbides
COIL SIZE	16" — I.D. Max. coil wt. 1000#
PACKAGING	On skids — shrouded

SIZE	14 x .040
ANALYSIS	1095
FINISH	Bright
HARDNESS	95 to 105 Rockwell B suitable for blanking
THICKNESS TOLERANCE	± .0005 incl. crown
WIDTH TOLERANCE	± .005
MICROSTRUCTURE	Uniform medium size spheroids
COIL SIZE	16" — I.D. Max. coil wt. 600#
PACKAGING	On skids — shrouded

Knowing exactly what you require for most efficient fabrication and most effective product performance, J&L can set up and consistently meet restricted specifications to match your most exacting demands. Often production operations can be greatly simplified or even eliminated; in most instances end-product and/or assembly costs can be reduced and quite frequently, product quality improved.

We would welcome an opportunity to explore with you the possibilities of J&L Restricted Specifications applied to your strip steel requirements.

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Now there are four J & L plants with facilities for production of "Restricted Specification" cold rolled strip. Strategic locations at Youngstown, Indianapolis, Los Angeles and Kenilworth, N. J., provide the security of 4 sources of supply plus the close working relationship which these local production centers make possible

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in hot salt quenching and salt bath quenching of gears. *Ajax Electric*

651. Sand Systems
Bulletin No. SL-3 shows layout of system and controls. *Harry W. Dietert*

652. Shear
Bulletin on bar and billet shear for rounds, squares, flats, billets and structurals, either hot or cold. *Hill Acme Co.*

653. Spectrochemical Analysis
28-page brochure on basic fundamentals of spectrochemical analysis. Methods, instruments, accessories described. Bibliography. *Jarrell-Ash*

654. Spectrographic Sources
4-page bulletin 35A on spectrographic source unit gives data on three units available. *Baird Atomic*

655. Spray Painting
New 6-page booklet on airless spraying. How it works, advantages. *Nordson*

656. Stainless Castings
Bulletin on advantages of corrosion-resistant castings. *Ohio Steel Foundry*

657. Stainless Fasteners
24-page catalog 56-A lists sizes and types. 7000 items included. *Star Stainless Screw*

658. Stainless Steel
24-page booklet on stainless bar and wire. Forms available, grades. Advantages, properties, fabrication, electropolishing, ebonizing. *Armco Steel*

659. Stainless Steel
8-page catalog of stainless sheet and plates. Analyses, finishes, sizes. *Easten Stainless Steel Corp.*

660. Steel
Data on low alloy steel. Chemical analysis, physical properties. *Youngstown Sheet & Tube*

661. Steel Castings
Folder contains chart of grades analysis, properties, comparable specifications for usual casting steels. *Induction Steel Casting Co.*

662. Sub-Zero Treatment
12-page booklet on industrial chilling equipment for shrinking, testing and treating of metals. *Cincinnati Sub-Zero*

663. Swaging Machines
16-page catalog on complete line of swaging equipment contains data on rotary swaging process and its applications. *Fenn Mfg. Co.*

664. Temperature Control
4-page bulletin on Pyrotac for automatic protection against excess temperature. Wiring is diagrammed. *Illinois Testing Labs.*

665. Temperature Control
Selection of thermal elements for use in 400 corrosive materials. Protective well and socket material. *Partlow Corp.*

666. Tempilstiks
"Basic Guide to Ferrous Metallurgy", a plastic laminated wall chart in color. *Claud S. Gordon*

667. Testing
Literature on pickle pills for testing strength of pickling solutions. *Ferro*

668. Testing Machines
12-page catalog on ten testers including hardness, ductility, tensile, compression and transverse strength. *Detroit Testing Machine*

669. Testing Machines
New 32-page Bulletin No. 54 on universal testing machines. Specifications, and loading, weighing and indicating systems. *Tinius Olsen*

670. Testing Machines
New 28-page catalog on fatigue testing machines. Specifications, working principles. *Riehle*

671. Testing Machines
Bulletin on Brinell hardness, ductility, compression, tensile, universal, transverse, hydrostatic proving instruments. *Steel City Testing Machines*

672. Thermocouples
Revised 8-page Catalog No. 32 on thermocouple and thermocouple wires. Charts on calibration symbols and wire color codes, wire resistance weights, properties. *Thermo Electric*

673. Thickness Tester
Data sheets give ranges, principle of operation of nondestructive thickness tester. *Unit Process Assemblies*

674. Thickness Testing
10-page Bulletin 2253 on coating thickness gages. Standard and special purpose gages. *American Instrument*

675. Tin News
Interesting monthly report covers important current developments in the production, marketing and use of tin. *Malayan Tin Bureau*

676. Titanium
24-page fact file gives physical and mechanical properties, metallurgy, corrosion properties, machining, forming and welding data. *Mallory-Sharon Metals*

677. Titanium Powders
Data on high purity and commercial titanium powders. *Hawkridge Metals*

678. Tool Steel Failures
124-page book, "Tool Steel Trouble Shooter", analyzes 107 tool failures and assigns causes as among tool design faults, tool steel faults, improper heat treatment, mechanical and operational factors. *Bethlehem Steel*

679. Tool Steels
Bulletin on tool steels, hot work specialty steels, bar stock, billet, sand casting, drill rod, flat ground stock and tool bits. *Darwin & Milner*

680. Tubing
Bulletin 3 on small tubing for industry. Sizes, alloys, tempers, tolerances. *Precision Tube Co.*

681. Tukon Tester
12-page bulletin 328 on Tukon micro and macro hardness testers. *Wilson Mechanical Inst.*

682. Vacuum Dryers
New Bulletin No. 630 on vacuum shelf dryers. Sizes and specifications. *F. J. Stokes*

683. Vacuum Furnace
6-page data sheets on high-vacuum furnace for operation at 3600° F. Specifications. *Richard D. Brew*

684. Vacuum Furnaces
Bulletins P8-20 and P4-28 on vacuum arc melting furnaces and pumps. *Consolidated Electrodynamics, Rochester Div.*

685. Vacuum Pumps
Data sheet 4700 on mechanical booster high-vacuum pumps describes their construction, operation and applications. *NRC Equipment*

686. Welding Electrodes
Report No. W5410 on low hydrogen electrodes for high alloy steels. *Harnischfeger*

687. Welding Stainless
New 12-page booklet—a guide to better welding of stainless steels. In question and answer form. *Arcos*

688. Wire Cloth
80-page booklet on applications, meshes, baskets, filters. *Cambridge Wire Cloth*

689. X-Ray
12-page bulletin on gamma radiography tells how to select the source, equipment, techniques and fundamentals of gamma radiation. *Picker X-Ray*

690. X-Ray Equipment
4-page folder on X-ray viewer. Advantages and applications. *Philco*

691. Zinc Coating
New booklet on zinc coated steel. *Weirton Steel Co.*

March, 1958

478	498	518	538	558	578	598	618	638	658	678
479	499	519	539	559	579	599	619	639	659	679
480	500	520	540	560	580	600	620	640	660	680
481	501	521	541	561	581	601	621	641	661	681
482	502	522	542	562	582	602	622	642	662	682
483	503	523	543	563	583	603	623	643	663	683
484	504	524	544	564	584	604	624	644	664	684
485	505	525	545	565	585	605	625	645	665	685
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487	507	527	547	567	587	607	627	647	667	687
488	508	528	548	568	588	608	628	648	668	688
489	509	529	549	569	589	609	629	649	669	689
490	510	530	550	570	590	610	630	650	670	690
491	511	531	551	571	591	611	631	651	671	691
492	512	532	552	572	592	612	632	652	672	
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496	516	536	556	576	596	616	636	656	676	
497	517	537	557	577	597	617	637	657	677	

METAL PROGRESS,

7301 Euclid Avenue, Cleveland 3, Ohio

Please have literature circled at the left sent to me.

Name _____

Title _____

Company _____

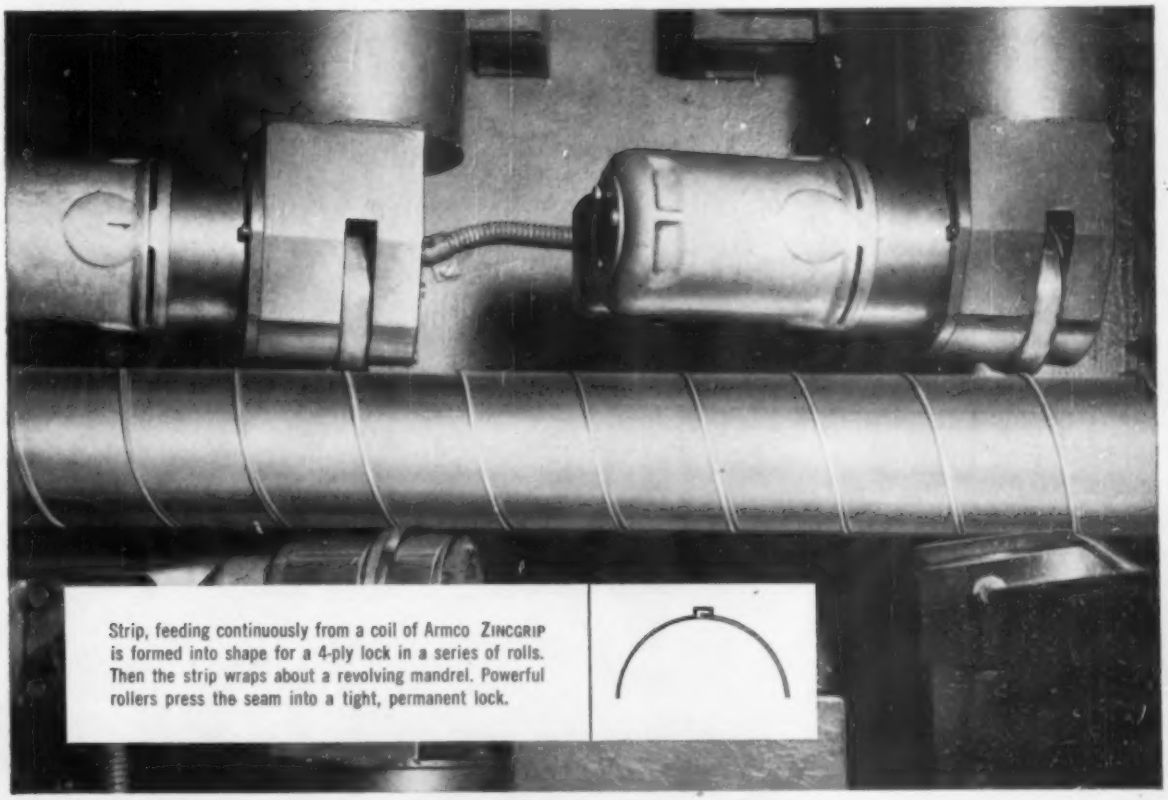
Address _____

City and State _____

Postcard must be mailed prior to June 1, 1958. Students should write direct to manufacturers.

in this continuous lockseaming operation . . .

Zinc coating on Armco ZINCGRIP Steel doesn't flake or peel



Strip, feeding continuously from a coil of Armco ZINCGRIP is formed into shape for a 4-ply lock in a series of rolls. Then the strip wraps about a revolving mandrel. Powerful rollers press the seam into a tight, permanent lock.

Here's in-shop evidence that the zinc coating on Armco ZINCGRIP® Steel clings tightly during severe fabrication.

This machine forms sheet metal into conduit with a continuous spiral lockseam. Few fabricating operations could provide so severe a test for a zinc-coated steel. But Armco ZINCGRIP Steel meets every requirement. Its special hot-dip zinc coating doesn't flake or peel.

This complete zinc protection is doubly important for the conduit. It not only wards off rust when exposed on construction sites, but resists corrosion in areas within buildings where maintenance is difficult or impossible.

If your products require drawing, forming, lockseaming, or any other severe fabrication, you can rely on Armco ZINCGRIP. Just fill in and mail the coupon for full information about this workable, zinc-protected steel.

Other Armco Steels for top-quality products include ZINCGRIP PAINTGRIP®, Stainless Steels, ALUMINIZED STEEL, Cold-Rolled PAINTGRIP, Enameling Iron, Steel Tubing, Electrical Steels, High Strength Steels, Long Ternes, and high-quality Hot- and Cold-Rolled Sheets.

ARMCO STEEL CORPORATION
1348 Curtis Street, Middletown, Ohio

SEND complete information about Armco ZINCGRIP.

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Firm_____

Street_____

City_____ Zone_____ State_____

ARMCO STEEL

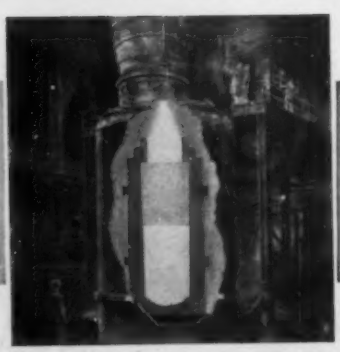
ARMCO STEEL CORPORATION • 1348 CURTIS STREET, MIDDLETOWN, OHIO

SHEFFIELD DIVISION • ARMCO DRAINAGE & METAL PRODUCTS, INC. • THE ARMCO INTERNATIONAL CORPORATION

Donald O. Buker, Assistant Project Engineer, checks on an experimental melt in progress in the Stokes Vacuum Furnace. External controls and alloying devices afford complete access and manipulation of the melt.

THE METALS INDUSTRY IS PROFITING FROM THE USE OF OTHER STOKES PRODUCTION EQUIPMENT

Powder Metal Presses. Cost savings and the compacting of incompatible alloys have made powder metallurgy an accepted process. Stokes offers the most complete line of presses in the industry.



Steam Degassing Systems. Stokes offers production equipment which can control hydrogen content of steel to less than 1 ppm by removing the gaseous impurities from the molten metal.

Vanadium Corporation of America keeps Stokes Vacuum Furnace busy in Ferroalloy Research

A Stokes Vacuum Furnace System, installed in the Cambridge, Ohio Research Center of Vanadium Corporation of America is kept constantly on the go . . . exploring new ideas that someday may be applied to production procedures for ferroalloys and master alloys. Investigations include the degassing of alloys produced by commercial production practices, and the melting of metals too reactive to be satisfactorily processed in normal atmosphere.

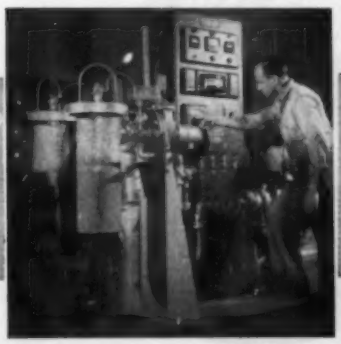
For example, various vanadium-containing alloys have been remelted . . . to determine property improvement and extent of gas removal under specified temperature and pressure conditions. Another use involves the melting of higher titanium-content alloys which would oxidize excessively in air. The research center is also concerned with alloys containing boron, calcium, lithium, chromium, magnesium, columbium and tungsten.

T. W. Merrill, Director of Product Research, advises "we have found that the furnace performs very satisfactorily, and has met all our expectations in this regard."

Stokes Vacuum Furnaces are extremely flexible, ruggedly built units, designed for developmental or production runs . . . in sizes ranging from 17 lb. to greater than 5,000 lb. melts. Production units are fully engineered with charging and mold vacuum locks for semi-continuous operations. In all these units, a broad selection of accessories and features is available. Of particular interest is the fact that, as in the case of Vanadium, Stokes easily makes special customer accommodations to meet individual requirements.

Complete technical information and specifications are available on Stokes Vacuum Furnaces and accessories. For detailed application engineering, the Stokes Advisory Service is available for consultation and recommendations concerning your exact requirements. Write today.

Vacuum Equipment Division
F. J. STOKES CORPORATION
5500 Tabor Road, Philadelphia 20, Pa.



Heat Treat Furnaces. Compact Stokes vacuum furnaces are available for many commercial heat treating applications. Sequenced and centralized controls afford utmost convenience in handling of work and cycles.

STOKES

1470 AB

HANDIMET GRINDER

A New, Wet Hand Grinder for Metallurgical Samples

Now you may have wet grinding facilities for hand preparation in your laboratory at a nominal cost. Convenience at your fingertips, always clean and ready for use. Simply attach to water and drain facilities.

Individual elevated hard glass grinding surfaces are continually flushed with streams of water. This floats off the surface removal products, provides lubrication, and leaves sharp abrasive edges exposed at all times. A control valve permits complete selectivity of the volume of water. Ample drainage facilities with standard pipe fittings are provided at the rear. The grinding platforms are pitched downward and away from the operator.

The Handimet Grinding Paper is coated with a pressure sensitive adhesive backing and firmly holds when merely pressed against the flat grinding surface. It is easily removable when sheet is worn.

No. 1470 AB HANDIMET GRINDER, complete $98.00

No. 1469-SW AB HANDIMET GRINDING PAPER for 1470 Grinder, Grits 240, 320, 400, 600 per 100....$10.00

No. 1469-1-SW AB HANDIMET GRINDING PAPER assorted 10 each grits 240, 320, 400, 600....$4.50

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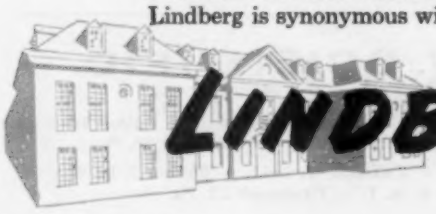
METALLURGICAL APPARATUS

2120 GREENWOOD ST., EVANSTON, ILLINOIS, U.S.A.

How to find a better heat-treating method

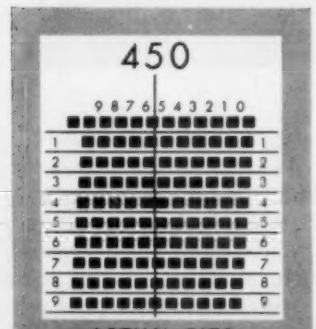
Here's a sound way to do it. Take your problems to the people who have consistently, over the years, provided the metal treating industry with new and better ideas, more efficient, more practical equipment. This will bring you to Lindberg, creators of the famous Cyclone type atmosphere furnaces, the long-life "dimple" vertical radiant tube, the revolutionary new CORRTHERM electric heating element and so many other innovations in better heat treating methods. Lindberg is synonymous with heat treating furnaces. We build them for carbonitriding, carburizing, hardening, tempering, normalizing, bright stainless annealing, brazing, carbon correction, nitriding, or any other metal treating requirement. Give your production processes the advantages of Lindberg's forward look in "heat for industry" techniques. Get in touch with your nearest Lindberg Field Representative (See classified phone book) or write Heat Treating Furnace Division, Lindberg Engineering Company, 2448 W. Hubbard St., Chicago 12, Illinois.



LINDBERG heat for industry

Weighing is the heart of all analytical procedure

To keep pace with increased laboratory work loads balance manufacturers have developed balances that weigh faster, are easier to operate and require *no operator technique*. The NEW Christian Becker Model NA-1 single pan, semi-automatic balance provides everything the chemist has wanted. Fast accurate weighings are as easy as 1 - 2 - 3.



TEN THOUSAND DIVISION OPTICAL READOUT

New, large, easy to read reticle and vernier eliminates Balance squint.

1. Place sample on pan, close door, select "rough weighing" beam by rotating knob "A".
2. Weight control knobs "B" are then rotated. Weight indicator lights "C" *indicate if weights have to be added or removed.*
3. Final 1000 mgs., or any part thereof are recorded on new, large, easy to read reticle and vernier, after fine weighing beam is put in use. This ten thousand division optical readout "D" is absolutely unique. It eliminates completely "balance squint." The large number at the top plus the vertical line show that the weight is between .455 and .456 gram. By following the line down, it makes a solid rectangle at "4", thus giving a reading of .4554. This plus the weight recorded on counter "E", gives total weight of sample.

ANYONE CAN OPERATE THIS BALANCE

It also includes many other features:

- External zero adjustment—temperature compensation
- Oil damping—longer "Pan-to-Stirrup" dimension
- Exclusive two-beam construction—one for rough weighing—one for fine
- Weighing and pilot lights to indicate beam in use
- Stainless steel Class M weights
- Knobs for weights and beams are at convenient table height
- Weight counter and reticle and vernier are at eye level.

Capacity 200 grams. Sensitivity .1 mg. Readability .05 mg. Catalog #H1830 . . . Price $1,185.00
(4 page bulletin available on request)

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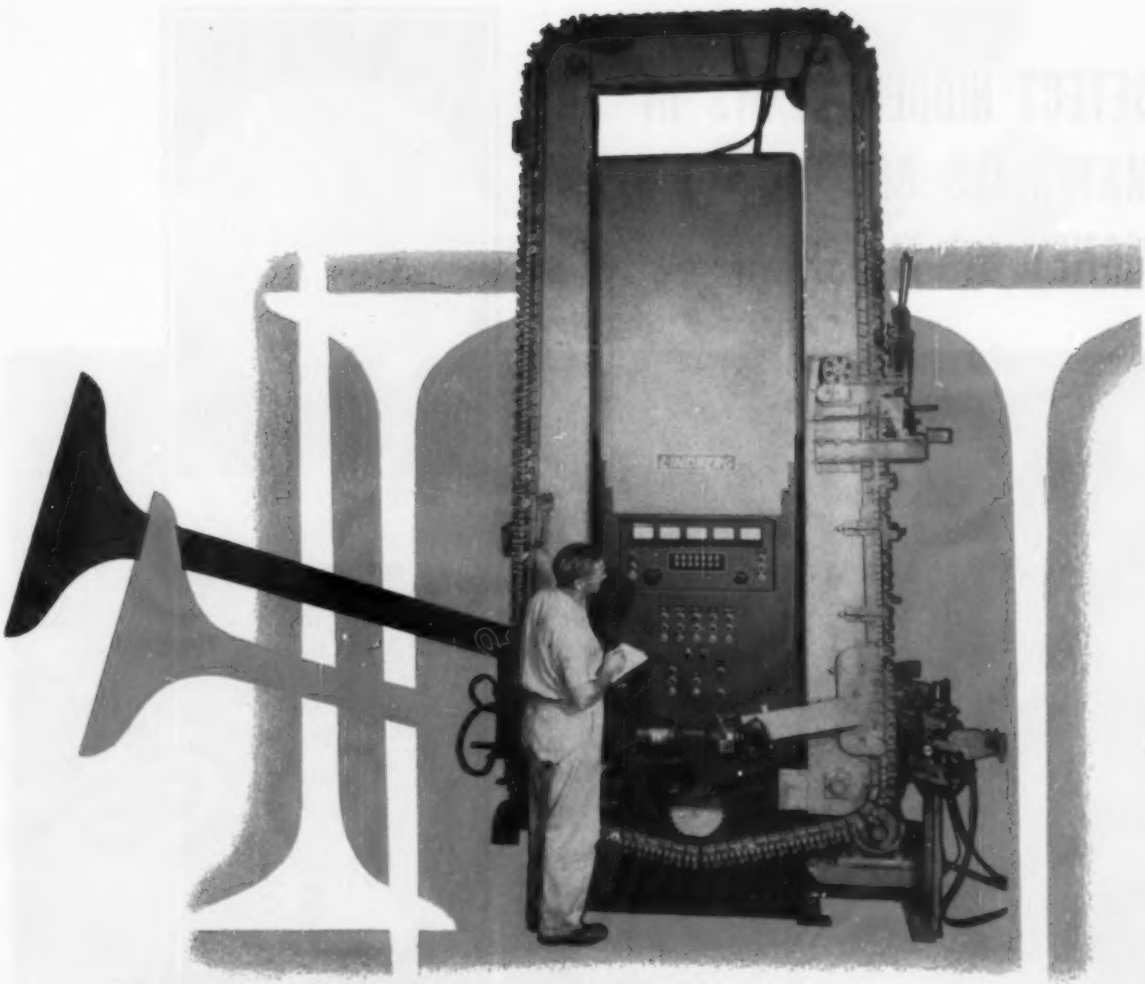


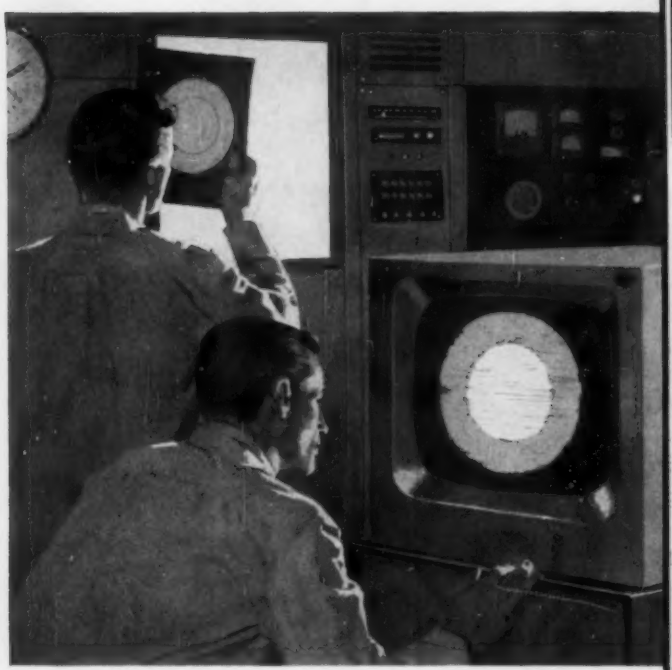
Lindberg pioneers in High Frequency Heating

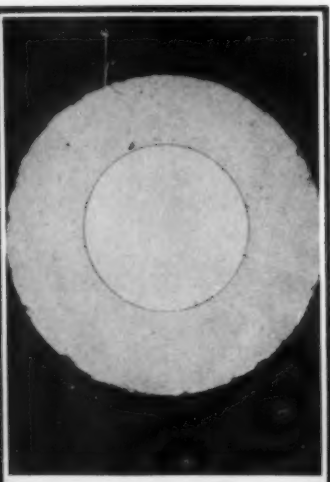
Along with its pioneering in all phases of "heat for industry" Lindberg is one of the largest makers of High Frequency heating units. Our "H-F" designers and engineers have made outstanding developments in this important heat treating field. For example, we illustrate a remarkable unit just recently completed for aluminizing automotive valves. It was designed vertically, saving 60% of floor space, and is completely automatic. No operator is required. It fits perfectly into an automated production line.

Our High Frequency Division provides units for hardening, brazing, heating for forging and forming, annealing and many other processes, and designs a variety of fixtures for application to "H-F" units. Lindberg also supplies a complete line of motor generators for all induction heating and melting applications. Get in touch with your nearest Lindberg Field Representative (See classified phone book) or write High Frequency Division, Lindberg Engineering Company, 2448 W. Hubbard St., Chicago 12, Illinois.

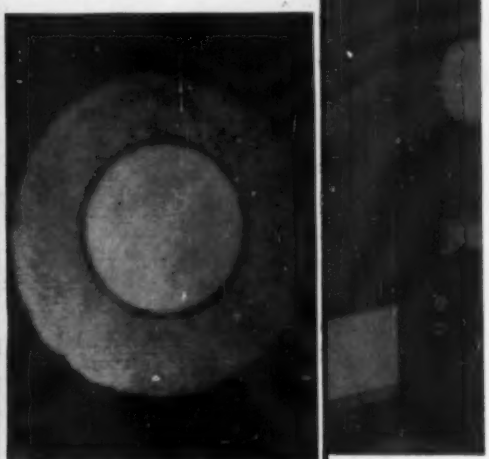
LINDBERG heat for industry

DETECT HIDDEN FLAWS IN MATERIALS BEFORE YOU SPEND MONEY ON FINISHING!





Actual photograph of gray-scale test transparency, shown unenhanced.



The same transparency showing gray-scale contrast enhancement by EXICON.

New Philco EXICON dramatically improves gray-scale contrast on any photographic transparency.

EXICON is proving an invaluable new tool in metallurgy, quality control, stress analysis and countless industrial applications. This new dimension in contrast enhancement is finding application wherever greater detail is desired in the reading of any photographic negative. If you have a problem requiring contrast enhancement . . . Philco's new EXICON system may provide the answer.

Exicon®

PHILCO®

GOVERNMENT AND INDUSTRIAL DIVISION

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At Philco, opportunities are unlimited in electronic and mechanical research and engineering.

Lindberg applies the creative touch to field-installation

Here is an example of Lindberg's creative touch in field-installed heat treating equipment. Our unique design of this movable overhead furnace saved space, labor and time and increased quality and operating efficiency in missile manufacturing. We have the technical staff and the experienced engineers to design and install for you any requirement you may have for the application of heat to industry. Our service covers all types of heat treating furnaces, aluminum melting and holding furnaces, high frequency units, ceramic kilns, controls and all facilities required to fit this equipment into your production processes. We specialize in "turn-key" operations covering everything from design and engineering to the finished job installed in your own plant. Whatever your industrial heating problem, a good way to solve it is to talk it over with Lindberg. Just get in touch with your local Lindberg Field Representative (See classified phone book) or write Lindberg Industrial Corporation, 2321 West Hubbard St., Chicago 12, Illinois. Los Angeles Plant: 11937 S. Regentview Avenue, at Downey, California.

LINDBERG heat for industry

How Thompson Products saves $9,750 a month descaling titanium parts in hot Virgo bath

In this plant of Thompson Products, Inc., titanium forgings become mirror-smooth blades for aircraft turbines. But first, workers must get rid of the tough black oxide scale that forms on the parts during forging and heat treating.

They used to *blast* scale loose with a special zirconium sand imported from half-way around the world. But the sand was expensive—$10,000 a month. It had to be purchased and stored 4½ carloads at a time. Stacked in bags, it ate up valuable space—and made a mess when heavy bags burst.

Then this company called in a Hooker sales-service man who showed how they could get the scale off *chemically*. He recommended Virgo Descaling Salt at a cost of only *$250 per month* instead of $10,000 for sand.

Parts come clean in 4 dips

Now titanium parts ride in stainless-steel baskets through four dip tanks—and come out with not a trace of scale. In five minutes in the first tank, molten Virgo salt at 850°F removes almost all of the stubborn scale. In successive dips, cold water removes the adhering molten salt, acid quickly removes the residual soft oxide and hot water rinses the parts clean.

The process descales stainless steel and other high-temperature alloys, too—simply by raising temperature of the salt another 100 degrees. There's no attack on the metal itself at any stage.

It's easier now for inspectors to see tiny defects in the smooth, chemically clean surface of these parts; so quality control is better than before.

Maintenance costs are lower, too: just four dip tanks that need occasional replenishing with salt and acid.

Have you a tough scale problem? Perhaps a talk with a Hooker representative will open a way to substantial cost reductions for you. If you'd like to discover how, just drop us a note on your business letterhead.

HOOKER ELECTROCHEMICAL COMPANY
403 Union Street, Niagara Falls, N. Y.

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This modern boat trailer uses Youngstown Pipe for strong all-welded steel construction of its boat cradle and main trailer chassis.

YOUNGSTOWN CONTINUOUS WELD PIPE

. . . provides extra-strength chassis for "Texan" boat trailers

Here's an unusual application for steel pipe. "Texan" Boat Trailers, produced by the Cunningham Trailer Works of Lubbock, Texas, are fabricated from Youngstown Pipe to provide users maximum cargo protection as well as greatest ease during loading, unloading and while making the haul.

In line with Cunningham's policy of using only the highest quality raw materials, they wisely specify Youngstown Continuous Weld Pipe for fabrication of both the boat cradle and main trailer chassis. This gives Texan boat trailers a sturdy welded steel construction able to withstand the most rugged use—on or off the highway. Why not use Youngstown Pipe structurally to build strength and quality into your products?

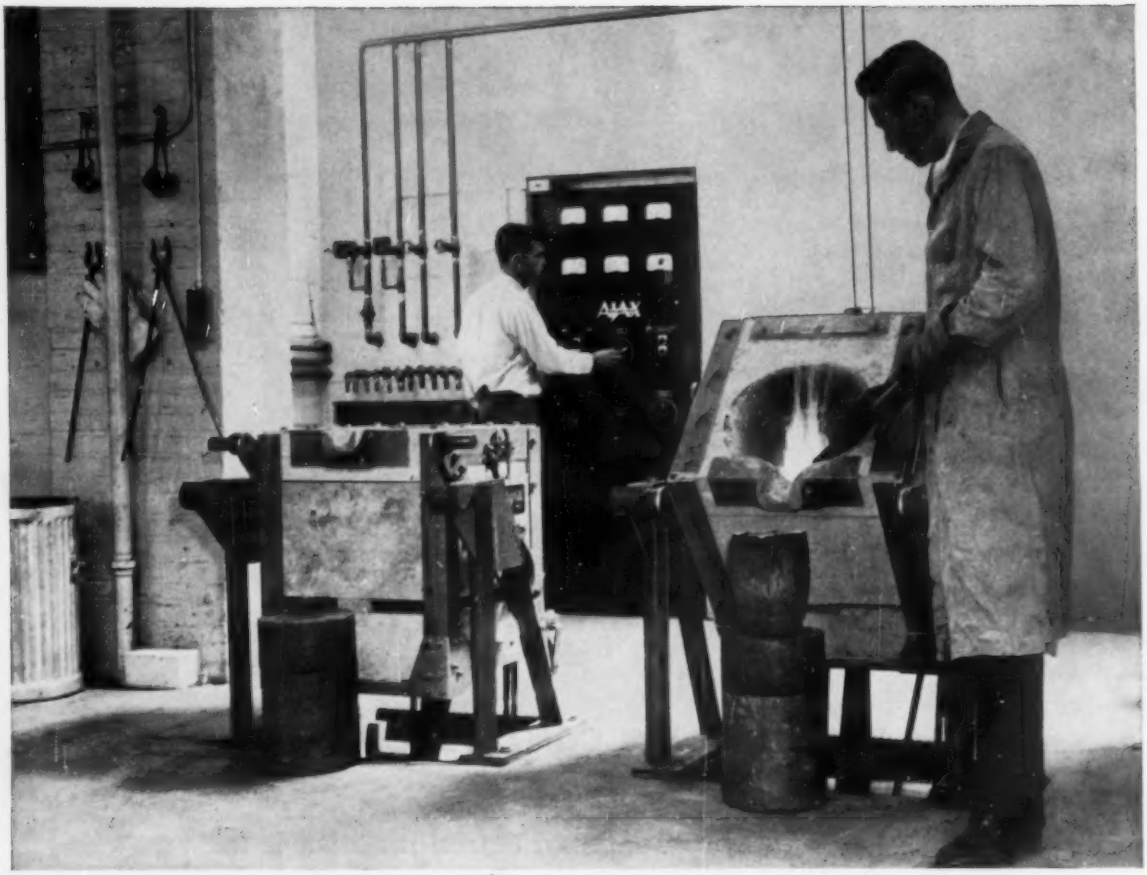
Your local Youngstown Distributor is the man to call when you want quality pipe—day or night. He has a complete stock and his on-the-spot fast delivery will help keep your operations humming along at top speed. Why not call him today?

Next time you need pipe—for any purpose—specify Youngstown and secure these 7 Points of uniform goodness

- uniform ductility
- uniform lengths
- uniform threading
- uniform weldability
- uniform wall thickness and size
- uniform strength and toughness
- uniform roundness and straightness

QUALITY YOUNGSTOWN SERVICE

THE YOUNGSTOWN SHEET AND TUBE COMPANY
Manufacturers of Carbon, Alloy and Yoloy Steel
General Offices - Youngstown 1, Ohio
District Sales Offices in Principal Cities



HIGH FREQUENCY INDUCTION HEAT IN THE LABORATORY

For the laboratory metallurgist, the moment of truth is in the melting furnace. More likely than not, the crucible he turns to is set in the helix of an Ajax-Northrup induction coil. For ever since its discovery, high frequency induction heat has been instrumental in the birth of new metals.

The *clean* heat of the induction furnace has ushered in alloys unmarred by impurities . . . has permitted the successful development of vacuum metallurgy. Its precise control of heat permits alloying as the metallurgist desires —no longer at the mercy of chance. And the stirring action inherent in Ajax-Northrup induction melting has actually made possible many new metals and alloys.

There you have just a few of the advantages that make Ajax-Northrup furnaces a laboratory standby. Even in this day of computers, spectrographs, and electron microscopes, they are assured an important place in the search for the unknown . . . the study of the known.

Available in capacities from a few pounds to several thousand pounds, Ajax-Northrup furnaces may be powered by economical converters or heavy duty motor generator sets. Write for Catalog.
Ajax Electrothermic Corp., Ajax Park, Trenton 5, New Jersey.

Induction heating & melting

AJAX

NORTHRUP

ASSOCIATED COMPANIES: AJAX ELECTRIC COMPANY-AJAX ENGINEERING CORPORATION

These typical 19 together took 91

Here are 19 discriminating buyers whose 91 orders and reorders prove complete satisfaction with these UNITRON instruments.

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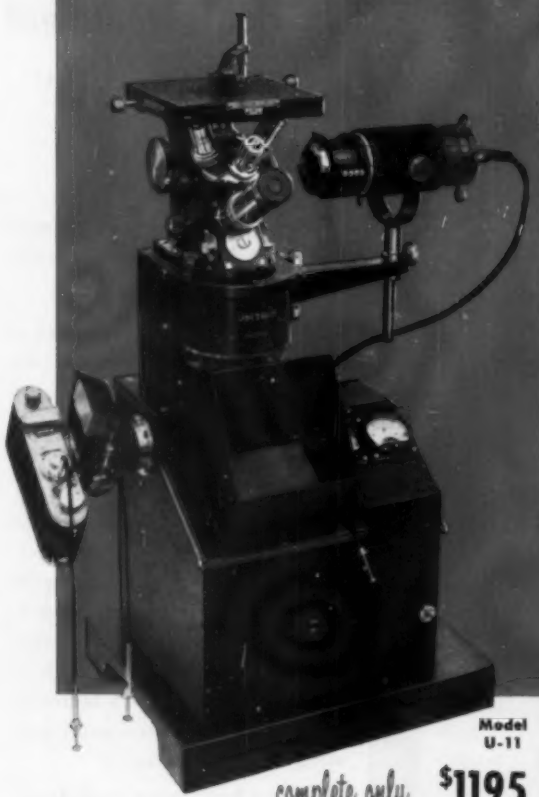
GENERAL MOTORS	I. B. M.	U. S. GOVERNMENT
GOODYEAR ATOMIC	M. I. T.	UNIV. OF CINCINNATI
NATIONAL CASH REGISTER		UNIV. OF WASHINGTON
U. S. STEEL	GENERAL ELECTRIC	R. C. A.



Model U-11

complete only **$1195**

BINOCULAR MODEL only $1379

UNITRON METALLOGRAPH and Universal Camera Microscope, Model U-TI: A completely self-contained instrument of modern design for visual observation, photography, projection and measurement of both opaque and transparent specimens, using bright-field, dark-field or polarized illumination. While compact in size, it duplicates the performance of large, cumbersome instruments. Even laboratories on a limited budget can enjoy the accuracy, speed and efficiency possible only with a complete installation of this type.

- Standard optics include 5 parfocal objective lenses with revolving nosepiece, 4 photographic eyepieces on a revolving turret, 3 visual eyepieces, all coated. Magnification range: 25-2000X.
- High-intensity illuminator with variable transformer built into the microscope base.
- Built-in 3¼" x 4¼" camera. The image is automatically in focus in the camera and transition from observation to photography is instantaneous.
- Calibrated square mechanical stage with calibrated rotatable stage plate.
- Calibrated polarizing apparatus, transmitted-light accessories for transparent specimens, filters, micrometer eyepieces, film holders, cabinets, dustcovers, etc. all included.
- Additional accessories, available at extra cost include: Polaroid Land Camera attachment for "60-second" photography; 35mm camera attachment; low power (5-40X) objectives; vacuum heating stage for temperatures to 1100°C.

Model MEC

complete only **$399**

BINOCULAR MODEL only $399

UNITRON INVERTED Metallurgical Microscope, Model MEC: Many of the features of the UNITRON Metallograph U-11, which are connected with visual observation of opaque specimens, are included in this compact unit. Think of the time which can be saved in your laboratory by providing each metallurgist with one of these handy, inexpensive units for use at his desk. Model MEC is also ideal for use together with a polisher or microhardness tester.

- Standard optics include 4 parfocal objective lenses: 5X, 10X, 40X, 100X oil immersion on revolving nosepiece; 3 eyepieces: P5X, Micrometer 10X, Ke15X, all coated. Magnification range 25-1500X.
- Vertical illuminator with iris diaphragm. Transformer housed in microscope base. A microswitch on the base provides an extra high intensity for photography.
- Binocular model has provision for attaching 35mm camera to microscope base. A 35mm camera attachment is available to attach to the eyepiece tube of the monocular model.
- Calibrated square mechanical stage with calibrated rotatable stage plate.
- Calibrated polarizing apparatus, 5 filters, dustcover, cabinet, etc. all included.
- Additional accessories available at extra cost include: 35mm camera attachment; K20X eyepiece for 2000X; transmitted-light accessories for transparent specimens; vacuum heating stage.

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on any UNITRON MICROSCOPES . . .

Let the instrument prove its value to you — in your own laboratory — before you decide to purchase.

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"Park Chemical Gave Us 50% Greater Production In Heat Treatment of Saw Blades"

Says Ray Uhl

Chief Metallurgist, Henry Disston Division, H. K. Porter Company, Inc., Philadelphia.

"One of the great advantages of using Park's salt baths is the uniform temperature, prevention of decarburization and the maintenance of excellent straightness that is obtained.

"We have stepped up production heat treatment 50% by preheating saw blades in Park's Nu-Sal Neutral Salt at 1600 degrees F. for 1½ minutes. Then we transfer to Park's high heat bath at 2200 degrees F for 45 seconds, and quench in neutral salt operating at 1100 degrees F.

"We have been using Park products for many years and have found that day-to-day uniformity of quality and the excellent service guarantee a high quality Disston saw blade."

Park neutral salts are balanced mixtures designed to provide positive neutrality, excellent fluidity and great stability. Their melting points and working ranges have been planned to furnish a neutral salt for every heat treating temperature from 925° to 2400° F.

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• • •

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Metal Progress
Volume 73, No. 3 March 1958

A New Editor— An Expanded Editorial Field

IT GIVES ME the utmost satisfaction to announce that Allen G. Gray has been appointed Editor of *Metal Progress* and entered into his new duties with the American Society for Metals on February 1. Ernest E. Thum, Editor since the foundation of the magazine in 1930, assumes the title of Editor-in-Chief. Marjorie Rud Hyslop, closely associated with *Metal Progress* since the beginning and officially the Managing Editor since 1952, retains her position and title, and her work will be supplemented by that of Carl R. Weymueller, newly appointed Assistant Editor. Dave Ritchie, who has been Assistant Editor since late 1956, completes the staff working full time out of the Cleveland office.

We believe that this talented group will be able to continue the development of *Metal Progress* in pace with the extraordinary tempo of modern technical and scientific advances, and further enhance its prestige and unique position as the Magazine of Metals Engineering.

Allen Gray is well grounded both in the engineering and the editorial demands of the new position. He has been a consulting editor and frequent contributor to *Steel* since 1942, and became Technical Editor of that leading business magazine in 1952. He is 42 years old, a graduate in both chemistry (B.S.) and metallurgy (M.S.) from Vanderbilt University of Tennessee, with a Ph.D. in chemistry from the University of Wisconsin in 1940. His postgraduate studies were on molybdenum steels and tungsten alloys.

The 12 years between graduation and taking up editorial work with *Steel* were in the employ of the Du Pont Co., working at one or another of the manifold problems of metal processing, primarily their chemical aspects. In the early 1940's, for example, he was active in the development of the fast electrotinning process to conserve scarce tin, in the perfection of aircraft engine bearings, and in the electropolishing of stainless steels (he being responsible for the commercial process now widely used). In the later war years he was loaned to the "Metallurgical Laboratory" at the University of Chicago, became one of the team which solved the critical problem of canning the uranium slugs for the Hanford atomic piles. During 1951-52, he was associated with the Du Pont Atomic Energy Division on special assignment with the Knolls Atomic Power Laboratory of the Atomic Energy Commission. His continuing interest in develop-

ments of the atomic age is shown by his membership in the A.E.C.'s Advisory Committee on Industrial Information, and in the Governor's Advisory Council on Atomic Energy of the State of Ohio.

It is only necessary to say a few words about the editorial philosophy of *Metal Progress* to indicate how well such a man as Allen Gray fits into the picture. The magazine was founded in 1930, and Ernest Thum, the Editor, given a simple directive: "Create a monthly magazine which will attract the members of the Society by its good format, and carry illustrated articles about all phases of metal progress written in terms easily understood by metals engineers." At the same time, *Metals Review* was established to carry society news and the Review of Metal Literature – and of course the scientific *Transactions*, already in its 12th year, was continued. This complete separation of functions was a wise idea, as amply proven by events. *Metal Progress* quickly established itself as an engineering magazine and rapidly proved that it was not an organ of any group or dominated by any private interest.

Its importance to the American metals industry can be assessed by the fact that, through the years, from two thirds to three quarters of the readers (now numbering nearly 30,000) are in executive positions, departmental managers, supervisors, and engineers – men generally classed as "metals engineers", men capable of planning, supervising or managing the necessary fabrication operations on high-quality metals and alloys. Even during the relatively short life of *Metal Progress* the number of these men has multiplied sixfold, and the complexity of their interests and their sophistication has enlarged equally as fast. Hence, *Metal Progress* has yearly met (and I believe successfully met and will continue to meet) a continuing challenge for diversification and improvement. Things seem to go by spurts – maximum interest has changed from inspection methods, to heat treatment, to stainless alloys, to better quality in conventional steels, to atomic energy and a galaxy of "new" metals. There will be no end to these changes. We foresee in the immediate future an intense development of materials for high-speed flight, for heat engines, for missiles and control systems – in many instances met (and they must be successfully met) by improvements in materials and manufacturing methods already with us.

Allen G. Gray

Marjorie R. Hyslop, Managing Editor; Allen G. Gray, Editor; and Ernest E. Thum, Editor-in-Chief

The editorial directive to the enlarged *Metal Progress* team headed by Thum and Gray will be much as it always has been: "Collect and print the vital information about the expanding world of metals, necessary for the wide-awake metals engineer to meet his ever-widening obligations, all directed toward the paramount necessity of maintaining our nation the home of the free."

WILLIAM H. EISENMAN
National Secretary
AMERICAN SOCIETY FOR METALS
Publisher of *Metal Progress*

Surface Fatigue of Carbo-Nitrided Steel

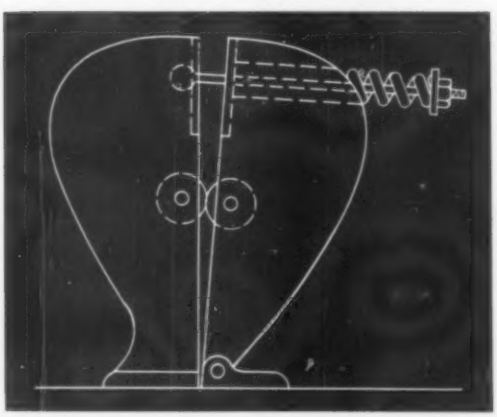
by G. W. POWELL, M. B. BEVER† and C. F. FLOE†*

The pitting of worn carbo-nitrided surfaces is shown to be related to case depth and amount of retained austenite. Performance of carburized surfaces, run in conjunction, indicates case depth to be the prime factor (Q7, Q9, J28m; ST)

THE CARBO-NITRIDING PROCESS of case hardening steel has been the object of a number of investigations, and much is known of the effects which process variables have on the cases produced and their structural features. Little, however, has been published on the properties, other than hardness, of carbo-nitrided cases and their performance in service. In the investigation reported here, the surface fatigue behavior was explored and compared with that of carburized steel. The effects of variations in case depth and retained austenite on the surface fatigue of carbo-nitrided specimens were determined, as well as cycles to failure versus applied load.

Surface fatigue, also called wear fatigue, is the deterioration of a metallic surface by pit formation resulting from cyclic loading of a surface layer. It is usually caused by cyclic rolling or sliding contact of two surfaces under high normal loads. Surface fatigue, therefore, is likely to be encountered in such applications as gears used for power transmission, heavily loaded cams, and ball bearings. An obvious method of combating surface fatigue is to give the surface adequate strength; for steels, this is often done by case hardening.

Fig. 1 – Schematic Drawing of Surface Fatigue Tester



The stress distribution in the surface layer of two rolls compressed elastically along a line joining their centers may be found by an analysis first made by Heinrich Hertz[1]. The most important result of this analysis, certainly from an engineering standpoint, is that the shear stress reaches a maximum value at a point *below* the surface of contact. The depth, Z, of maximum shear stress for two steel rolls of equal radii is

$$Z = 0.000153\sqrt{PR}$$

where P is the load per unit length measured along the line of contact and R is the radius of the rolls. The pressure, Q, at the center of the area of contact of steel rolls is

$$Q = 3240\sqrt{P/R}$$

Hardened steels subjected to conditions of wear fatigue display two types of pitting[2]. In every instance, small nondestructive pits are observed. These pits are shallow and attain at most a depth of approximately 0.005 in. This phenomenon is referred to as incipient pitting. The second type of pitting is destructive. Parti-

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†Professors, Department of Metallurgy, Massachusetts Institute of Technology, Cambridge.

Support of this work by the Ammonia Div. of Armour and Co., Chicago, is gratefully acknowledged. Thanks are due to Prof. E. Buckingham for the use of special surface fatigue testing equipment and to P. A. Clarkin for conducting some of the tests.

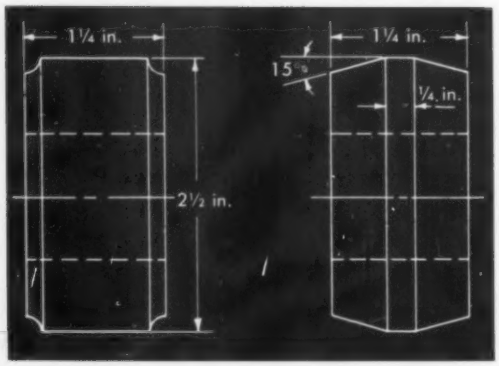

Fig. 2 – Standard and Test Roll Designs. Test rolls are beveled to concentrate the load

cles of thickness equal to or greater than the depth to the point of maximum shear stress are removed from the surface. While *incipient* pitting is believed to originate at surface cracks which develop at right angles to the surface, *destructive* pitting is caused by subsurface cracks which form in planes parallel to the surface[3]. Cracks of these two types have also been observed by Rosenberg and Jordan[4] in studying the effects of oxygen on the wear of steel.

Tests on carburized A.I.S.I. 2515 show that for a given load the fatigue life increases with the case depth[3]. These observations have led to an empirical rule according to which the case depth should be twice the depth to the point of maximum shear stress for full resistance of the case to wear fatigue.

Experimental Methods – The testing equipment used consisted of a fixed and a pivoted

Table I – Carbo-Nitriding Treatments

Code	Treatment	Case Depth
A	4 hr., 1600° F.	0.030 in.
B*	4 hr., 1600° F.	0.030
C*	6 hr., 1600° F.	0.037
D*	8 hr., 1600° F.	0.042

*These specimens were refrigerated at −108° F. for 30 min. and stress-relieved at 375° F. for 90 min.

frame and is sketched in Fig. 1. Each frame supported an arbor on which one of the rolls was mounted. A calibrated spring drew the frames together and thus applied a radial load to the rolls. The arbor holding the standard roll was driven by an electric motor; for pure rolling experiments, the friction between the rolls drove the test roll. The test, which was conducted at a rate of about 10,000,000 cycles per week, was terminated automatically by the vibration of the apparatus when the test roll became destructively pitted.

The rolls are shown in Fig. 2. The standard rolls (shown at left) were machined from a 1.1% carbon steel, hardened and tempered to Rockwell C-62 to 64.

Profiles of the test rolls were beveled in order to concentrate the load. They were machined from A.I.S.I. 1020 and the test surface was ground before case hardening. The various carbo-nitriding treatments given to the test rolls are summarized in Table I. In addition, three rolls were carburized for 3 hr. at 1700° F. to the same case depth, 0.030 in., as that of the specimens carbo-nitrided by treatments A and B. They were then tempered to the same hard-

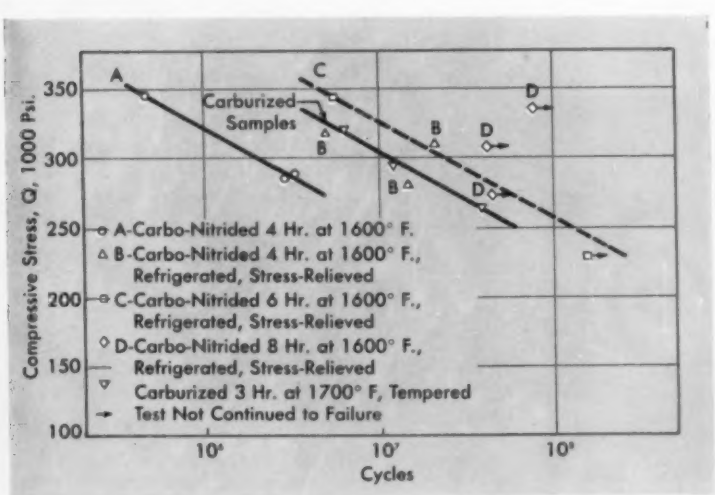

Fig. 3 – Graph of Surface Fatigue Data for Various Carbo-Nitriding Treatments

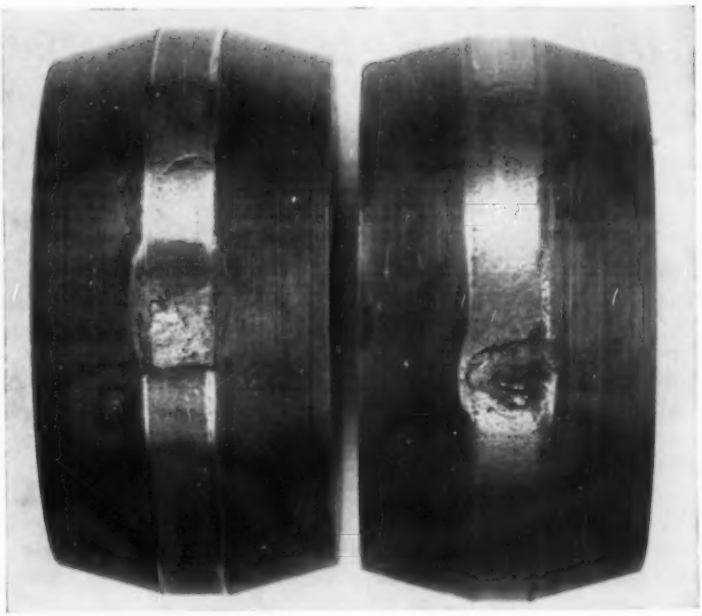

Fig. 4 – Typical Examples of Destructive Pitting. Specimen on right carbo-nitrided 4 hr. at 1600° F.; specimen on left carbo-nitrided by a special treatment at 1350° F.

ness as the specimens in Group A, which was approximately C-57.

The specimens carbo-nitrided for 4, 6, and 8 hr. at 1600° F. were refrigerated at −108° F. for 30 min. to remove most of the retained austenite. This treatment increased the hardness from C-57 to C-62. After refrigeration, these specimens were stress-relieved for 90 min. at 375° F., without any decrease in hardness.

Discussion of Results – Figure 3 shows, for the various case hardening treatments, the cycles to failure versus the compressive stress, Q, calculated by the equation given above. Four of these tests were terminated without failure after a long period, but are included because they furnish useful information. The type of destructive pitting which caused the majority of failures is illustrated in Fig. 4. Incipient pitting of the test surface is also noticeable in this figure.

The line marked "Carburized Samples" in Fig. 3 shows that a single line may represent approximately the wear fatigue behavior of both the carburized and tempered cases and of the carbo-nitrided and refrigerated cases B of the same case depth (0.030 in.), even though the hardness of the latter case was greater (C-62 versus C-57). This suggests that the case depth was the factor which determined when failure occurred.

Line A in Fig. 3 represents carbo-nitrided specimens which differ from those marked B in that they have been neither refrigerated nor stress-relieved. They suffered incipient pitting and flaking-off of the surface layer of the case. The major factor contributing to the poorer fatigue life of the A specimens probably was the presence of retained austenite in the case, although the comparison is complicated by the additional stress-relief given to samples B.

Points B, line C and points D are for carbo-nitrided specimens with case depths of 0.030, 0.037, and 0.042 in., respectively. These data indicate a large improvement in fatigue performance resulting from an increase in case depth. An increase from 0.030 to 0.042 in. raises the fatigue life by at least a factor of 20. The depths of the large pits formed in the specimens with case depths of 0.030 and 0.037 in. were at least equal to the total thickness of the case. The depth to the point of maximum shear stress did not exceed 0.020 in. in these tests.

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Modern Metallography

*Reported by H. P. ROTH**

One of the meetings arranged for the Second World Metallurgical Congress in Chicago early last November was organized by the U. S. Atomic Energy Commission's Internal Group on Metallography, and considered many advanced metallographic techniques using ultraviolet and visible light, X-rays, emitted rays, and electron beams. (M 20, M 21, M 23)

THE THURSDAY SESSIONS on Metallography at the last ASM Annual Convention (Nov. 7, 1957) arranged by a combined committee of the American Society for Metals and the U. S. Atomic Energy Commission were a smashing success, as evidenced by the attendance. Particularly in the morning, the crowd became so large that seats had to be put in the aisles. The roster of speakers and of guests included names of many of the famous in the world of metallography, and the speakers did not let us down – they were both interested and interesting.

R. J. Gray of Oak Ridge National Laboratory presided as chairman of the sessions on advanced metallographic techniques by virtue of the fact that he led the A. E. C.'s Internal Group on Metallography which planned the program. Cyril S. Smith started the proceedings with the historical background, much more lively and absorbing than normally to be expected of anything historical. After discussing Japanese etch patterns produced in metals as early as 1600 A.D., he described the very good work of the 18th and 19th century on etching of metals to produce beautiful and delicate patterns. It was not until considerably later that this development of structural patterns was recognized as a means for manufacturing control by relating the etched structure to production procedures. He also pointed out that autoradiography is not new, showing a picture exhibiting very good detail made by this method in April 1879, only six months after X-rays were discovered! Later on, when he was called upon to present a sort of summary and critique of the morning's topics, he stated that he could say with certainty that all the papers presented were good except the first which was his own, but this reporter would say the truth is that *all* the papers were good, including his own.

A large number of 2nd World Metallurgical Congress Conferees from foreign countries were noted throughout the audience, among them Otto Loebich and Wolfhard Reich of Germany, B. C. Woodfine and W. Steven of England, and J. P. B. Hugo of South Africa. Also, there was present perhaps the most highly concentrated gathering of metallographic notables, both American and otherwise, ever seen together in one place – and all of high standing as measured in terms of valuable metallographic studies and contributions to technical literature.

Surface Preparation – L. E. Samuels of Defense Standards Laboratories, Alexandria, N. S. W., Australia, talked about the early theories of flow, wherein metal was not thought to be removed or cut off during grinding, but supposed to melt and be redeposited as an amorphous layer, like glass. He contends it is not necessarily true that such a Beilby layer exists. He described work designed to establish the effect of traces remaining on metallic surfaces after the scratches themselves had apparently been removed. In order to utilize epitaxial phenomena for this purpose, thin copper plating was applied and cross sections of the metal examined to see whether the plating had continued to form single grains directly over locations where whole grains were at the contact surface on the base metal. Subgrains in the plating apparently indicate discontinuities or deformed areas in the metal below. These

*Supervisor, Nuclear Metals, Inc., Cambridge, Mass.

would be the locations of previous scratches not entirely removed.

Following this, E. C. W. Perryman of Atomic Energy of Canada (Chalk River), described work attempting to reveal structure through surface treatment. Certain planes in metals are known to be thermodynamically stable and quite resistant to etching. His discussion included the practice of anodizing between re-annealing treatments to show grain boundary migration. He gave tribute to the valuable work of Jacquet and of Samuels in relieving cold worked surfaces of metals such as copper and brass. From this he proceeded to the "climb of dislocations" and an explanation of why pits form at dislocations. In copper-zinc alloys, zinc ions are known to concentrate at dislocation points. This confirms the opinion that solute atoms may concentrate at dislocations. He also warned against making erroneous interpretations because of solute atoms which have precipitated out and redeposited on the specimen's surface.

Incident Light Microscopy – G. L. Kehl of Columbia University, New York City, had as his topic "Incident Light Microscopy", but concentrated on quantitative measurement of surface contour by (*a*) the interference fringe method and (*b*) the profile microscope method. Monochromatic light is essential for interference microscopy because of aberration introduced by its angle. The method is suitable for measuring differences of from 20 millimicrons to about 2 microns in depth, and one can determine from the interference fringes whether or not a discontinuity is an elevation or a depression by the direction of the "sawtooth points" with reference to an index mark. A sawtooth leads the fringe motion if the area is raised and it follows the fringe if depressed. Where there is a deep groove or very great differences in surface level, white light is used to trace fringes of the same order which are difficult to match; white light shows the fringes to be of different colors and each band can be traced by its individual color.

For the profile method a wire is inserted at the microscope diaphragm, and it casts a shadow on the specimen plane. Any wanderings of the shadow from a straight line are attributable to deviations in the specimen's surface and can be measured. While the method has certain disadvantages, it can be used for differences of 0.3 to 100 microns. The open discussion compared this method with Tolansky's method and the 45° angle. These methods might be useful in studying hydrogen attack on grain boundaries, but it is apparently hard to tell whether the grain boundaries have fissured or not.

Early Work With Ultraviolet – The chairman introduced Francis F. Lucas, the same Lucas for whom the Grand Award of the annual Metallographic Exhibit was recently named. In a brief extemporaneous address, he talked about his early work in ultraviolet microscopy. Undoubtedly, it was a good combination of speaker and topic because, according to his own good-humored introduction, he does not in the least mind referring to himself as a sort of a "nut" on the subject. He said that sometimes a metallographer, being intensely interested in the research he is doing, gets off on a side street (as Lucas appeared to do) and later it happens that he is not in an alley at all but really on what turns out to be a main street!

In 1900 an ultraviolet instrument was on the market and a number sold, but for quite some time there was little improvement in the equipment or its applications and accomplishments. Consequently the users or makers made no effort to improve the numerical aperture of the system. To Lucas and his colleagues at Bell Telephone Laboratories it became apparent that the prime difficulty was in finding the focal point. Their work involved evacuating and mounting so as to get rid of vibration. An electrical supply at 220 volts was stepped up by transformer to about 2000 volts to generate a spark for illumination. The pencil of "light" then emerging from the system required examination with an imitation eye. It was a long and arduous task and finally the depth of focus was determined to be 1/16 of a micron! It took many, many exposed plates to locate this point; obviously, the photographic emulsion was out of focus if it was placed ¼ of a micron ahead or beyond the correct point.

Lucas later became interested in the field of biology which can employ ultraviolet examination to particularly good advantage, for living tissue can be photographed to reveal layer after layer by refocusing successively right on down through the section. This is like photographing a top page of a book and then the succeeding pages below without turning the pages.

This address was an enthusiastic tribute from Lucas to modern microscopy. Upon its completion it was decided by common consent that there would be no further discussion solicited on the subject beyond what he had said. This was in the nature of a similar tribute being returned from microscopists to Lucas!

Emitted Rays — Sterling Newberry of General Electric Co., Schenectady, N. Y., discussed the examination of metal by means of autoradiography, microradiography and X-ray metallography. In evaluating these methods by comparing them with visible light microscopy (metallography, in the traditional sense), he made the following statement: "The metallograph is in the key position in identifying and interpreting structures, and it is rather doubtful that it will ever be replaced." So far, other instruments have enhanced the metallograph and not displaced it.

He showed how stereoscopic images can be made by microradiography by placing the sample on a rotating device to get a view representative of that seen by each eye of the viewer.

Limiting the thickness of specimens for X-ray metallography is more important than preparation of a fine surface finish. Number 00 polishing paper usually produces a surface which is good enough, but 0.040 in. of metal is too thick, since it would require high voltage to penetrate it with resultant loss in resolution.

Near the end of his presentation, Mr. Newberry projected a short movie which had been taken by placing the camera without a lens above an X-ray microscope. It demonstrated good and poor resolution of a 1500-mesh grid and a 200-mesh screen. It included pictures taken at about three frames per second of a wasp on a piece of scotch tape, showing the varying densities of the insect organs with the shadowgraph effect typical of fluoroscopy. Next, a live ant was shown in the cell and then a spider entered. The spider was very lively and resisted radiation much better than an ant. He continually attacked the nearly dormant ant, creating the impression of a boxing match. The movie at three frames per second also showed the crystalline growth of mercury amalgamated on aluminum.

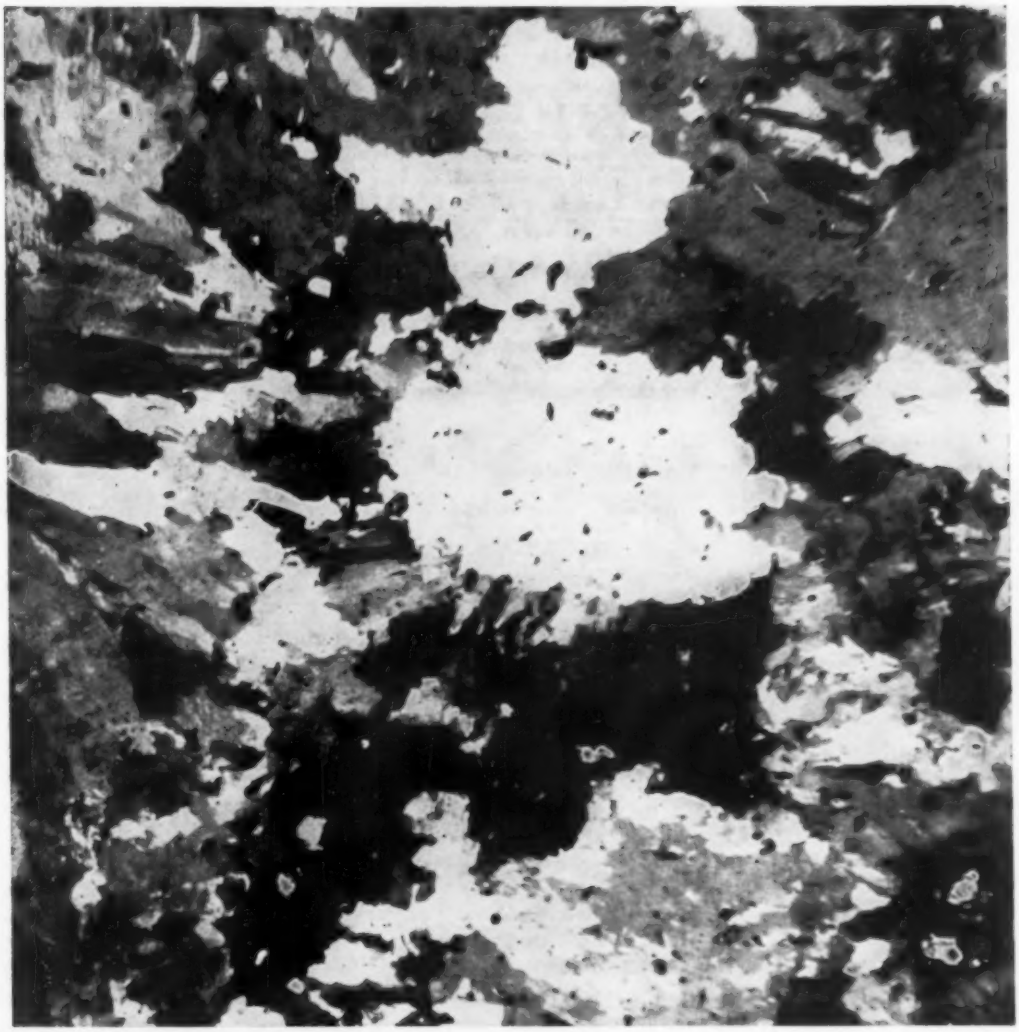
In discussion, J. B. Newkirk commented on the desirability of placing the film unusually close to the sample. In this way the X-ray method might be used to study dislocations. He showed an example of a single crystal of silicon iron containing substructure as shown by angular illumination with X-rays reflected to fine-grained film placed very close to the sample.

Electron microscopy was the topic of the last paper (by W. C. Bigelow, Dept. of Chemical and Metallurgical Engineering, University of Michigan). He thinks it unfortunate that metallographers were among the last to apply this instrument to any great extent, although at present it seems to be quite in vogue. The Metallographic Exhibit this year indicates this, since almost 20% of the 500 entries are electron micrographs. He described the Radio Corp. of America's instrument with projector system which gives magnifications as high as 200,000. Since about two microns is usually regarded as the limit of resolution for the electron microscope, this one is reputed to go down to 0.1 to 0.2 micron. Commenting on replicas, it was observed that 700, 800 or even 1000 Angstroms of thickness is necessary for plastic replicas but carbon replicas can be one-third that thick; likewise the carbon is not affected by the electron beam.

Summary — At this point Cyril Smith was invited to give a summary and critique. He commended those people inclined to work empirically; and this reporter feels that his words are appropriately timed. During the last few months, the people of the United States are being told, and quite correctly so, that they should be vitally aware of the great need for more formal technical background, more scientific education. Every means of public communication repeats this over and over again. The words of Dr. Smith do not contradict this; they only add balance to it. They offer additional inspiration to those very valuable people engaged in scientific work who are blessed with visual acuity, diligence and much natural curiosity. By using such valuable resources, these of our scientific personnel who cannot stop to study other things formally can at least *study* in performance the work they are doing. They can observe much and improve much upon the knowledge we now have.

Following are some of his words: "I am impressed by one main thing in the broad field of metallography; the way things grow up, become mature, and then seem to decay for a short time until something happens to recreate interest. Metallography was not nearly so interesting ten years ago as it is now." Then he extolled people who do things empirically: "who look at things with their eyes. For instance, we saw dislocations years ago and were not really looking at them. We were proud of surfaces which were devoid of such things as etch pits. Ultimately, of course, we want things to be examined carefully from a scientific angle, but where would we be if it were not for those people who have discovered so many things through curiosity and careful observation?"

First Photomicrograph of Plutonium



For many years following the first reduction of plutonium to metal, no trick of metallography could be found that would reveal any semblance of grains or grain boundaries in the room-temperature (alpha) phase, with or without polarized light. After some promising tries by Fred Schonfeld and Eugene Cramer at Los Alamos Scientific Laboratory, Clayton O. Matthews* in early 1954 was able to develop a metallographic procedure that would reproducibly reveal differences in crystal orientation in alpha plutonium (if the grain-orientation and grain-boundary hash that one sees can properly be called grains). Matthews sumitted the above photomicrograph to the ⚙ Metallographic Exhibit in 1955, but apparently the judges had no basis for appreciating his accomplishment.

The metal shown is "high-purity" Pu (99.97% by weight, 99.82 at.% at 500 ×. As a dilatometer specimen, it had been run through about a dozen thermal cycles between room temperature and about 500° C. The obvious (but not extensive) porosity (a few light spots in "high relief") is believed to have grown into the specimen as a consequence of the many phase transformations between allotropes, most of them anisotropic. ⚙

*C. O. Matthews is now director for materials at the Missiles Division of Lockheed Aircraft Co., Palo Alto, Calif.

Materials and Processes in Manufacture of Costume Jewelry

*By RALPH H. ATKINSON**

Skilled artisanship and mass production are combined to satisfy a growing demand for inexpensive jewelry with a fine jewelry appearance. (T9s, 17-57)

COSTUME JEWELRY, or "fashion jewelry" as it is sometimes called, is made in all the traditional jewelry forms and articles, which is only to be expected, because the buyer wants an object in the historic ornamental tradition (apart from the absence of precious metals). However, the industry broke away from the shackles of its origin and became more creative and less imitative with the lapse of time. An important step in this evolution occurred at the time of the depression, when established designers of precious metal jewelry turned to the designing of costume jewelry. Since that time, the industry has provided ample scope for top-flight designers and has benefited accordingly.

In the classification adopted in the U.S. Census of Manufactures, costume jewelry, costume novelties and ornaments made of all materials except precious metals and precious or semi-precious stones are included under the heading "costume jewelry". However, precious metals are not entirely excluded because much costume jewelry is plated with gold, silver or rhodium as part of the finishing process. The principal categories of costume jewelry are women's and children's jewelry (58%), men's jewelry (12%), and imitation pearls and imitation pearl necklaces (9%). Metals are an essential part of about 90% of the costume jewelry.

The costume jewelry industry has been growing steadily since World War II and is now of the same order of size as the precious metal jewelry industry; there is every indication that this growth will continue.

Probably well over 30,000 persons are employed in the manufacture of costume jewelry, because the Census figure of nearly 28,000 does not include those employed in the manufacture of costume jewelry findings (metal and plastic) and in the cutting and polishing of imitation stones.

The organization of the industry is similar to that of the precious metal jewelry industry. Small establishments are the rule. There were only two establishments with over 1000 employees at the time of the 1954 Census and 55% of the employees were in establishments with fewer than 100 employees. The geographical distribution of the two industries was also similar in 1954. Over 90% of costume jewelry was made in three eastern states, namely, New York (44%), Rhode Island (37%) and Massachusetts (12%).

Materials

The wide range of materials used for costume jewelry includes metals, plastics, glass and imitation stones, ceramics, enamels, shells, wood and leather. Materials might be used because they are novel or attractive in themselves, or as the base for an attractive finish.

Metals used for costume jewelry include brass and other copper-zinc alloys, copper, bronze, tin and tin-base alloys, aluminum, nickel, stainless steel. In addition, gold, silver, rhodium,

*Now retired, Mr. Atkinson was a metallurgist at International Nickel Research Laboratory. He resides in Westfield, N.J. This is the fourth and last in a series of articles on jewelry manufacture.

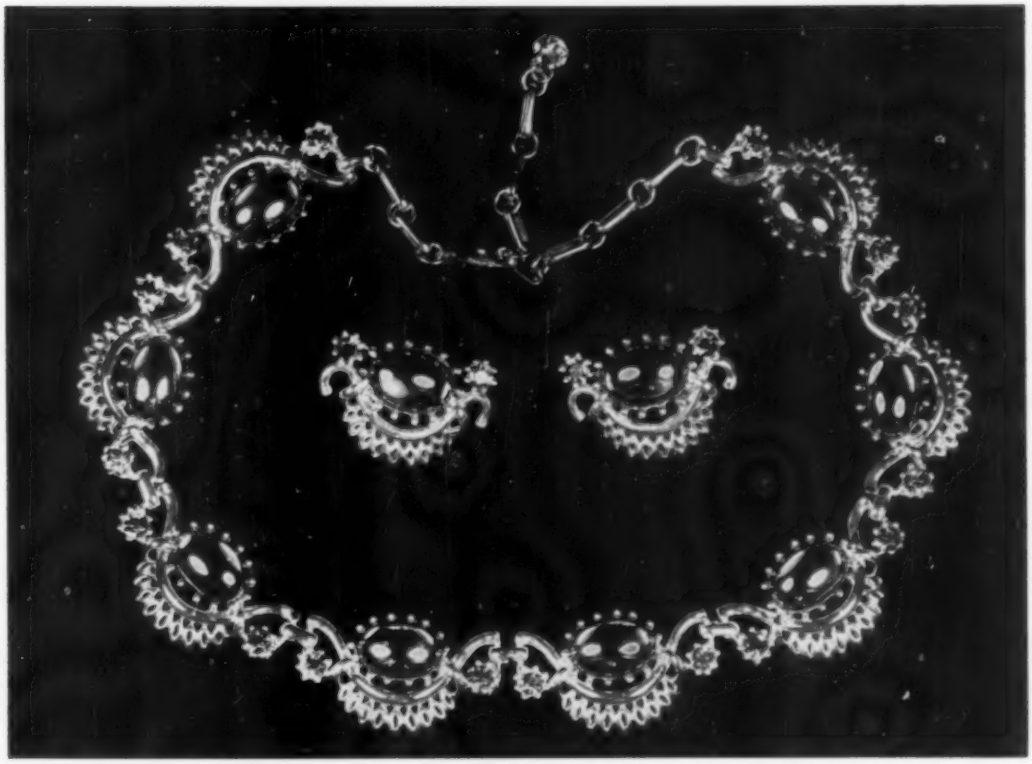


Fig. 1—Typical Examples of Modern Costume Jewelry. (Courtesy Coro, Inc.)

nickel and chromium are used as electroplates. Of these metals, brass (for stampings) and tin-base alloys (for castings) are by far the most important quantitatively.

Until recently, soldering difficulties have hindered use of aluminum for costume jewelry, but it is claimed that these difficulties have been overcome. In addition to an extremely pure grade of aluminum (for anodizing), a small amount of Alcoa 214 (3.8% Mg) is also used.

There are no official data for the actual consumption of base metals by the jewelry industry, but there are unofficial estimates for some of the metals for the year 1951, namely, 4,000,000 lb. of tin, 37,000,000 lb. of copper, 1,000,000 lb. of steel and 600,000 lb. of aluminum. This indicates the importance of this industry as a consumer of base metals.

Manufacturing Methods

In the manufacture of costume jewelry there has been a marriage of craftsmanship and mass production. Highly skilled craftsmen first carve models from solid tin according to drawings furnished by jewelry designers. Dies or molds are then made from the models. Steel dies are used for stamping. Molds for casting can be either steel, bronze or rubber. At this point mass production begins and pieces are made by the thousand either by stamping or casting. The stamped or cast pieces are then trimmed and any soldering is done at this stage, followed by polishing, plating and lacquering. Setting is the last operation if the stones are set with glue, but if setting involves deformation of the metal it will be done before plating. The preceding description or outline of the manufacturing process is not exhaustive, because as many as 38 operations can be involved in the manufacture of a piece of jewelry.

Methods used for processing the metals are in general similar to those used for precious metal jewelry except that the greater volume of costume jewelry compared with precious metal jewelry provides a greater incentive to the adoption of mass production methods. Fabrication processes include casting and various cold forming operations, the latter applied to strip, wire and tube. Tin-base alloys are cast, but the other metals are used chiefly as wrought

metal. Stampings predominate among wrought parts. Chain is machine-made by specialist firms. Settings are often cup-shaped stampings, which are better adapted for the rapid setting of stones than the more open type of settings used for diamonds. Some rings have precious metal settings. There is no technical justification for this type of setting, which is expensive both in material and labor.

Assembling includes such operations as soldering and "linking" (closing links either by hand or with the help of a machine). Soldering can be done by torch or electronically. In electronic soldering, which has superseded furnace soldering in modern factories, the findings and solder are placed in position on asbestos boards which have embossed patterns for the guidance of the operators. The boards are then placed on a conveyer belt which takes them through the heating zone of the electronic soldering machine.

Casting Tin-Base Alloys

Casting of tin-base alloys in rubber molds is of special interest because of its novelty, coupled with the fact that it is an instance of the mass production of castings in a permanent mold as simply and directly as possible. These alloys, which are better suited for casting than the other costume jewelry metals with higher melting points, are cast centrifugally in molds, either carbon steel or soft rubber molds. Metal molds have a longer life and are indispensable for higher melting alloys, but rubber molds are more economical for the tin-base alloys, especially for limited production runs.

Rubber molds are made from disks of unvulcanized synthetic rubber about 9 to 12 in. diameter by 1 in. thick. Two such disks are fitted in steel rings. After dusting the upper surface of the lower disk with French chalk, the patterns and three or four registering devices are placed on it and finally the top rubber disk is placed in position. The rubber mold is then vulcanized under pressure. After cooling, the die is removed from the press, the two halves parted and the patterns removed. The necessary central pouring gate and channels (sprues) can be molded in or cut with a sharp, wet knife after vulcanizing.

Finished molds are used on a centrifugal casting machine consisting of a motor-driven turntable revolving at speeds of 500 to 1200 rpm.,

Fig. 2—A Conveyer Belt Carries Costume Jewelry Parts Through an Electronic Soldering Machine. (Courtesy Coro, Inc.)

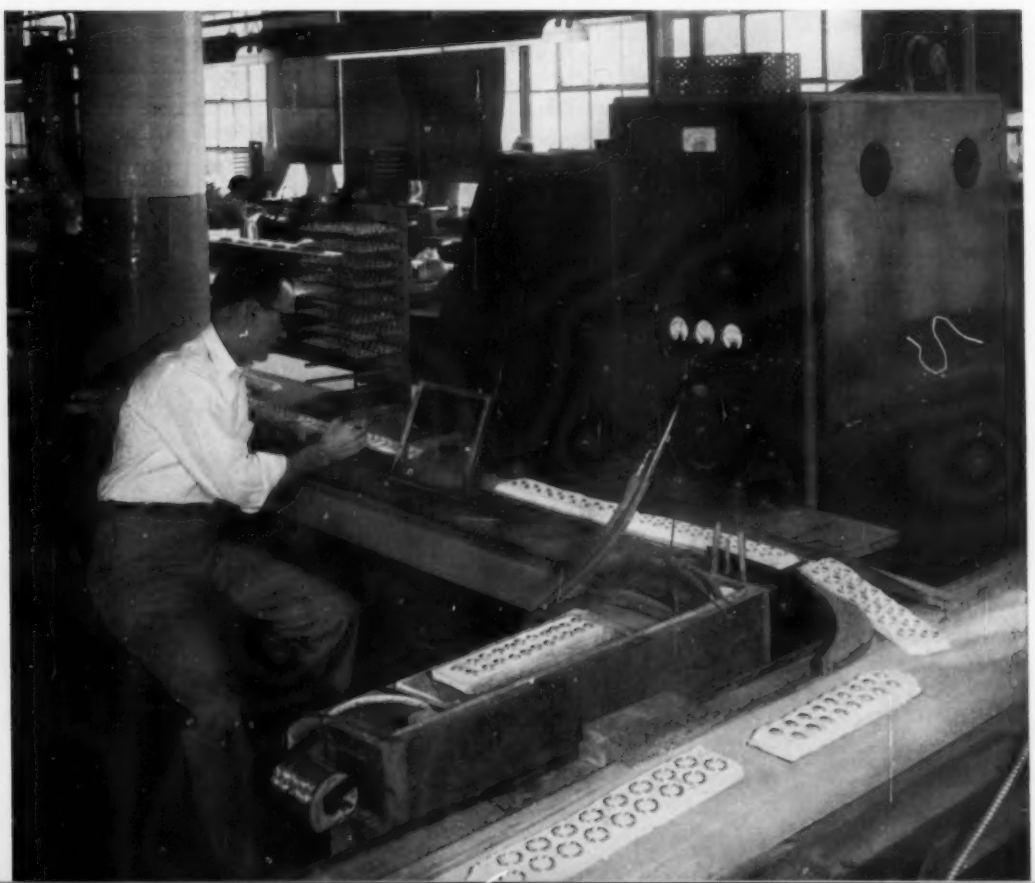


Fig. 3—A Typical Set-up for Centrifugally Casting Jewelry Shapes in Rubber Molds. (Courtesy Messrs. N. Saunders)

depending on the diameter of the die. In casting, the lid of the machine is closed and the mold set spinning. A controlled amount of metal is removed from the thermostatically controlled melting pot by a ladle and poured into the central hole in the mold, from where it is propelled into the mold cavities. The motor is then stopped, the mold stripped and castings removed complete with runners. After clipping off runners, the castings are ready for finishing.

For costume jewelry, castings are often given a light barrel burnishing with small steel balls and finished by bright nickel plating. The thin coat of nickel increases surface hardness of the castings considerably so that even the weakest alloys have ample abrasion resistance.

Choice of metal for this casting procedure is restricted because rubber molds deteriorate fairly quickly if the temperature of the metal exceeds 570° F. when it comes in contact with the mold. With temperatures below 570° F. the life of a mold is about 1000 casting cycles. The alloys found most useful for this work are basically tin with additions of antimony and copper to give increased strength and hardness. Die castings of other metals are much less important and more expensive to produce because their higher melting points require the use of steel dies.

Dimensional accuracy of castings made in rubber molds is good in the plane of the mold but dimensions perpendicular to the plane of the mold are often less than those of the pattern, probably because air can only escape along the parting plane. Consequently the process works best for relatively flat pieces. No such limitation applies in investment casting, but this process is normally considered too expensive for making costume jewelry.

Finishing

Finishing plays an especially important part in the manufacture of costume jewelry. The principal finishing processes are as follows:

1. Electroplating
2. Lacquering
3. Anodizing of aluminum

Electroplating is the usual finish for all metal parts, either wrought or cast, except aluminum. The polished pieces are wired to plating frames with soft copper wire (up to 100 pieces per

Table I — Statistical Data for Costume Jewelry Industry (U.S. Census of Manufacturers, 1954)

	Costume Jewelry	Precious Metal Jewelry
Number of employees	27,744	23,455
Number of plants	1,127	1,327
Value added by mfg., million $	129.2	145.6
Cost of materials, million $	110.2	112.6
Value of shipments, million $	239.4	258.2

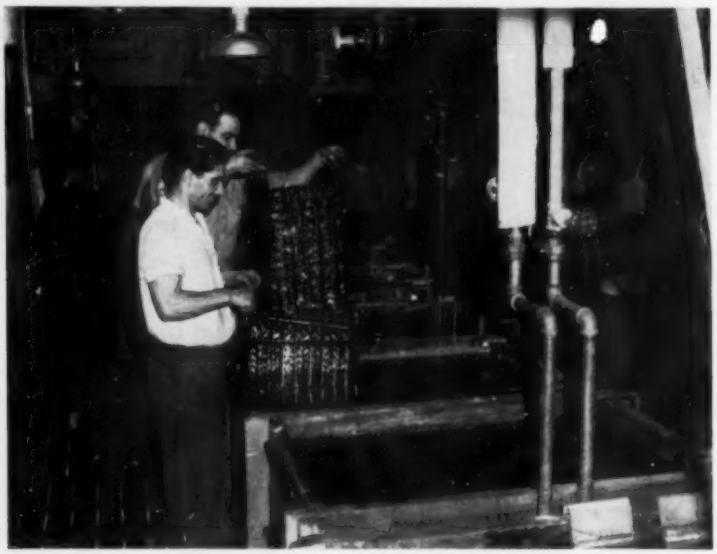


Fig. 4—Jewelry Is Wired to Cathode Frames for Electroplating if Pieces are Large Enough. Otherwise barrel plating is used

frame) and plated with bright nickel, with or without an undercoat of copper. Underplating provides protection against tarnishing. The final plating or coloring is then done in any desired color, as for example gold, silver or rhodium. Pieces which are too small for wiring are barrel-plated.

Gold plating of costume jewelry is more of an art than a science, because the object of the plater is usually to obtain shades of color which will have more sales appeal than the yellow color of pure gold. These shades of color are obtained by adding other metals such as silver, nickel, copper and tin to the gold cyanide plating solution. The resulting alloy plates are said to vary in composition from 14 to 22 karat; the plates are also extremely thin (from 0.000002 to 0.000005 in.) because thicker plates are not bright enough. "Bright plating" solutions are available for plating fine gold, but bright karat gold plating solutions are still in the research stage. Karat gold plating is done in a bath with insoluble anodes (platinum) with periodical additions of concentrated plating solution to replace the metals plated out or removed in the form of "dragout". Gold anodes can be used in baths for the electrodeposition of fine gold.

Gold electroplating of costume jewelry, which previously had been relatively free from rules and regulations, was recently (July 1957) brought within the scope of the "Trade Practice Rules for the Jewelry Industry" of the Federal Trade Commission. In the future "gold electroplate" will have to be not less than 10 karat and have a thickness equivalent to at least 0.000007 in. of fine gold. Thinner gold plates satisfying the minimum karat requirement may be marked "gold washed" or "gold colored". It is too soon to say how the new requirements will affect the gold plating of costume jewelry. Incidentally, it has been claimed that the manufacture of salts, solutions and anodes for the electroplating of gold is a multi-million dollar industry.

Lacquering—Synthetic lacquers used on costume jewelry include high-quality colorless transparent plastics, both thermoplastic and thermosetting. With the use of these synthetic lacquers and an undercoat of bright nickel, the manufacturer of costume jewelry has been able to retain the beauty of flash plates of gold and silver almost indefinitely in spite of their being very thin. Electroplated pieces are sprayed with the lacquer and baked in an oven at more than 250° F. It is claimed that some of the lacquers after appropriate baking treatments are as hard as porcelain.

Anodizing Aluminum—A small amount of aluminum costume jewelry is finished by anodizing by one of the commercial processes. High-purity aluminum, sometimes alloyed with 1% magnesium, gives the best results. The clear anodized finish can be made to give various tones of "silver" depending on the polishing pretreatments. The anodized surface can also be dyed with different colors, such as pink, blue and gold. One "gold" dye is the mineral pigment iron oxide, which is preferred to organic dyes where lightfastness is important.

A New Quenchant for Steel

By P. E. CARY,
E. O. MAGNUS
*and W. E. HERRING**

A solution of polyvinyl alcohol in water gives cooling rates between those of water and oil; medium-carbon steel parts can be readily hardened with little danger of cracking. (W28p, NM-b)

PROBLEMS INVOLVED IN the quenching of medium-carbon steel parts have plagued heat treaters for many years. Objects that would harden adequately in water were apt to crack; when oil was used instead, the cracking was eliminated, but the hardening response also dropped. In short, water cooled the parts too rapidly while oil cooled them too slowly. A quenching medium with a cooling rate between those of water and oil was needed. This gap is now partly filled by a new quenchant now in use at the International Harvester Co.

Polyvinyl alcohol, when mixed 5 to 30 parts by weight with 10,000 parts of water, will reduce the quenching rate enough to eliminate cracks in most instances. The quenching action is somewhat unusual. As the austenitized part enters the solution, the familiar vapor envelope forms. A viscous gel also appears around this envelope and the part stays hot much longer than it does when quenched in water. Cooling rate determinations prove that quenching is slowed appreciably by the gel. This insulating envelope collapses, and the part cools rapidly; contact with the liquid occurs in the last quenching stage. The gel forms again, and redissolves when the cooling is completed. A thin vinyl film, which retards rusting, remains. Figure 1 illustrates the times required for the collapse of the vapor envelope formed on specimens quenched in water and polyvinyl alcohol solutions.

The insulating effect of the film is best illustrated by end quench test results (Fig. 2). Different solution concentrations harden C 1053 steel at varying rates; the hardenability curves range between those produced by water quenching and oil quenching.

Preparation

Polyvinyl alcohol can be obtained in a 15% concentration water solution. A typical formula which includes a mold inhibitor and an antifoam additive follows:

15% STOCK SOLUTION FORMULA

Polyvinyl alcohol (DuPont Elvanol, Grade-50-42)	15.28 wt. %
Antimold (Du Pont "Shirlan A")	0.40
Antifoam (Dow Corning "Antifoam A")	0.40
Water	83.92

*Chief Research Metallurgical Engineer, Principal Research Metallurgist, and Research Metallurgist, respectively, Manufacturing Research, International Harvester Co., Chicago.

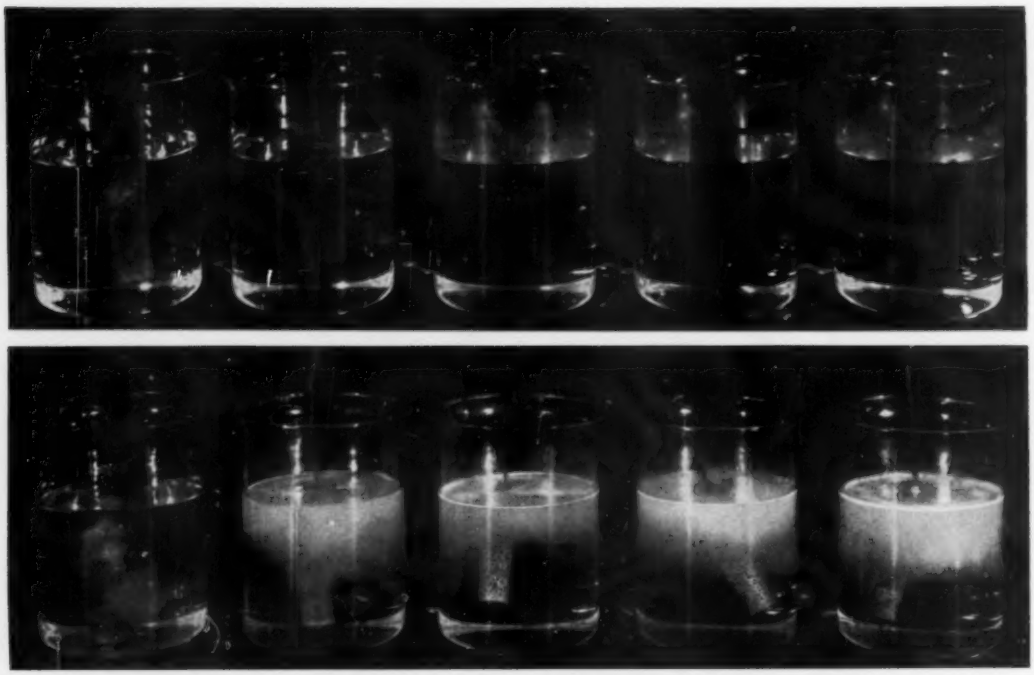


Fig.1 – Cooling Rate Comparison of Water (Top) and Polyvinyl Alcohol Solution (Bottom). Each beaker represents a 5-sec. interval; water quenching is complete in 15 sec. while the polyvinyl alcohol gel retards cooling for over 20 sec.

This stock solution is diluted to a 0.05 to 0.30% concentration which can be used equally well in either a pressure-spray quench system or an immersion quench tank.

The cost of this solution, as diluted for use, is estimated to be 2 to 3¢ per gal. A heat exchanger controls the solution at 90 to 110° F. normally, although as low as 60° F. and as high as 150° F. have been used. Pumps, heat exchangers, and fittings designed for use with water are suitable for the solution, providing exposed surfaces do not exceed 180° F. Otherwise, an insoluble solid, much like a varnish coating, is deposited.

Hazards

The quenchant is nonflammable as diluted for quenching. No indications of any skin troubles have been observed from the use of either the solid or water solutions. The experience of

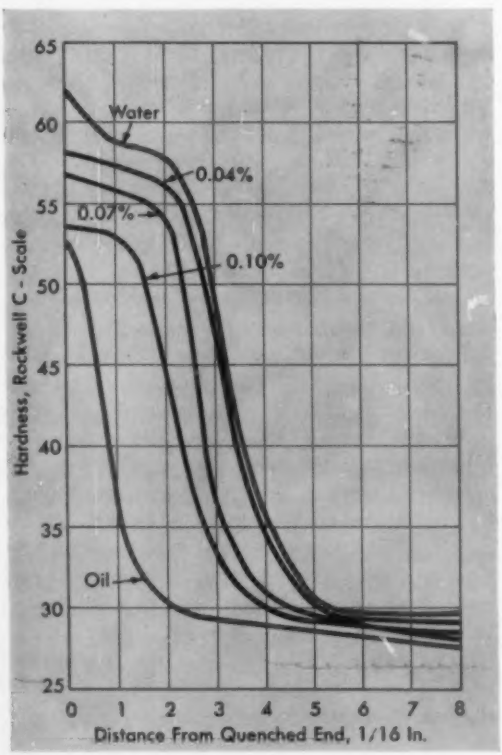


Fig. 2 – Hardenablity Curves for C 1053 Quenched With Water, Oil and Three Concentrations of Polyvinyl Alcohol. By varying the concentration and temperature of the new quenchant, a number of different cooling rates can be obtained

polyvinyl alcohol users in the textile and adhesive industries also indicates this material to be safe.

Applications

At present, no particular theory is advanced for the peculiar quenching effect, but in any production method, results are the final criterion. The method, whatever its actual mechanism, is very effective. Here are some examples.

Large gears of C 1045 steel with a 32-in. diameter and a 3½-in. face width were to be induction hardened. They were preheated to 600° F., rotated in an inductor and heated with 3000-cycle current. After austenitizing, the gear was quenched with water and tempered at 600° F. When water was replaced by the polyvinyl solution, the fatigue life was approximately tripled as the table shows.

Fatigue Life of Large Gears

No. of Tests*	Pressure Angle	Average Cycles to Failure†	Remarks
17	22°	79,000	Unpeened, water quenched, all failed.
8	22	234,800	Peened, water quenched, all failed.
14	22	281,000	Unpeened, 0.10% polyvinyl alcohol quenched, all failed.
4	22	668,800	Peened, 0.10% polyvinyl alcohol quenched, two did not fail.
6	25	469,500	Unpeened, water quenched, one did not fail.
11	25	940,000	Unpeened, 0.12% polyvinyl alcohol quenched, ten did not fail.

*Tangential load is 84,800 lb. in all tests.

†Tests which did not fail were stopped at 1,000,000 cycles and were included in the average.

The quenching solution improved fatigue life as much as shot-peening did; when both shot-peening and vinyl quenching were used, the greatest improvement was obtained.

Figure 3 shows the hardness depth attained in a large tractor rear axle made from C 1041 steel. Since this axle contained sharp splines and keyways, it could not be quenched in water without cracking, and oil quenching did not produce sufficient depth of hardness. A solution of polyvinyl alcohol produced satisfactory mechanical properties without cracking. In another application, the polyvinyl alcohol solution has been used to quench the oil pump gear of a camshaft. Previously made from C 1045 forgings, these gears were quenched in water; a shallow heat pattern was needed to avoid cracking. Oil quenching resulted in low hardness; a smoky, dirty operation was also experienced. The new quenchant produces a higher hardness and a thicker case than does oil, and no cracking occurs.

In tractor transmission gears, quenching with the polyvinyl alcohol solution has enabled us to substitute C 1050 for the more expensive C 1053 needed when the part was oil quenched.

Steering knuckles and transmission shafts are also being successfully quenched in this new medium. We feel that this new quenchant, while not a cure-all, fills a definite need, particularly for quenching medium-carbon steels.

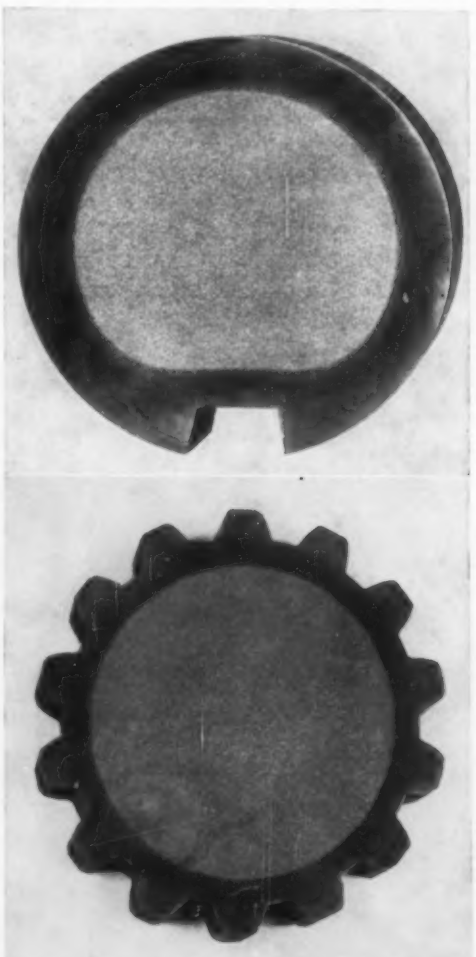


Fig. 3 – Tractor Rear Axle Shaft, C 1041, Induction Heated and Quenched in 0.15% Polyvinyl Alcohol Solution. The section has a 2.5-in. diameter

Improvement in High-Temperature Alloys by Boron and Zirconium

*By W. J. PENNINGTON**

While most tramp elements have been regarded as detrimental to high-temperature alloys, it is found that additions of 0.01% boron and 0.10% zirconium (or both), usefully reduce the tendency to notch brittleness at service temperatures and improve rupture strength.
(Q3m, Q26s, 2-60; SGA-h, Fe, Ni, Co, *Zr, B*)

IN 1930 the maximum operating temperature of gas turbine buckets was approximately 1300° F.; in 1940 it had been increased to about 1470° F. and in 1950 still further to about 1580° F. The duty of other components has gone up in similar fashion. These increases in operating temperatures could only have been achieved by the development of new alloys and improved melting and fabrication practices.

Modifications in chemical composition (increases in total hardener content) have been primarily responsible for the increase in high-temperature strength during the last 25 years. Recently conventional melting practices have been improved to the point that alloys with higher *average* rupture strengths can consistently be produced; however, there has been very little decrease in the amount of scatter of test results. To reduce this variation between successive test results, vacuum melting of superalloy grades has been introduced. The first commercial vacuum induction furnace in the United States was put into operation at Universal-Cyclops Steel Corp, in 1954 and trade named Inductovac®. Originally a 1000-lb. unit, it has since been modified to 2000-lb. capacity.

The alloys produced during the early days of vacuum-induction melting revealed small amounts of scatter but to a much lesser extent than in the corresponding air-melted alloys. According to F. T. Chesnut, writing in *Metal Progress*, December 1955, heat-to-heat variation was still a problem, indicating that there were

*Research Associate, Universal-Cyclops Steel Corp., Bridgeville, Pa. Acknowledgment is made to Kenneth Metcalfe, Chief Metallurgist, Bridgeville Plant, and Frank M. Richmond, Manager of Materials Research, for their contributions.

Table I – Nominal Composition of the Alloys

Element	M-252	J-1570	Waspaloy	Nimonic 90	A-289
Carbon	0.10	0.15	0.07	0.07	0.05
Chromium	19.0	20.0	20.0	20.0	15.5
Molybdenum	10.0	.....	4.0	.....	1.25
Cobalt	10.0	36.0	14.0	19.0	.....
Aluminum	0.8	.....	1.3	2.0	0.2
Titanium	2.5	4.4	3.2	3.2	1.95
Iron	1.0	1.0	1.0	2.0	Bal.
Tungsten	.....	7.0	.....	.....	.....
Vanadium	.....	.....	.....	.....	0.25
Nickel	Bal.	Bal.	Bal.	Bal.	26.0

some uncontrolled variables (generally attributed to differences in melting procedures which affected the total gas or inclusion contents, or both). An attempt to correlate these factors with resulting properties was unsuccessful and a comprehensive investigation was undertaken by the Universal-Cyclops research and development department.

The conclusions were quite striking. Mere traces of residual elements such as boron and zirconium were potent enough to alter strongly the high-temperature rupture life and rupture elongation. This is quite significant since rupture elongation is normally expected to decrease with increasing rupture life. Furthermore, small *controlled* additions of either boron or zirconium reduced the scatter in test data for any given alloy.

It was also discovered that boron or zirconium or both could get into vacuum-melted heats accidentally as contaminations of certain raw materials or from the crucible. R. F. Decker, J. P. Rowe and J. W. Freeman, working at the University of Michigan and reporting to National Advisory Committee for Aeronautics (Report No. 55, Jan. 18, 1957), have evaluated the effects of boron contamination from the crucible, made either of magnesia or zirconia.

As part of the investigations at Universal-Cyclops, small additions of both boron and zirconium were intentionally made to various nickel-base and cobalt-base heats and each heat evaluated. In addition, the effects of small boron additions to commercial, air-melted, electric arc furnace heats of the iron-base superalloy A-286 were evaluated. It was also necessary to devise accurate and reproducible chemical methods for the determination of small boron contents – which proved to be an important phase of the problem.

Vacuum Melting

A series of 1000-lb. heats, induction melted in vacuum, was made of the following grades: M-252, J-1570, Waspaloy and Nimonic 90. The nominal chemical compositions (except for boron and zirconium contents) have been listed in Table I. Melting was by standard vacuum-furnace procedures. All evaluations were made on one of four ingots from each heat. The first or control ingot was tapped prior to any boron or zirconium addition; the second ingot was tapped after an addition of either 0.005 to 0.01%

Fig. 1 – Effect of Testing Temperature on Tensile Properties of Cast Vacuum-Melted Alloy M-252

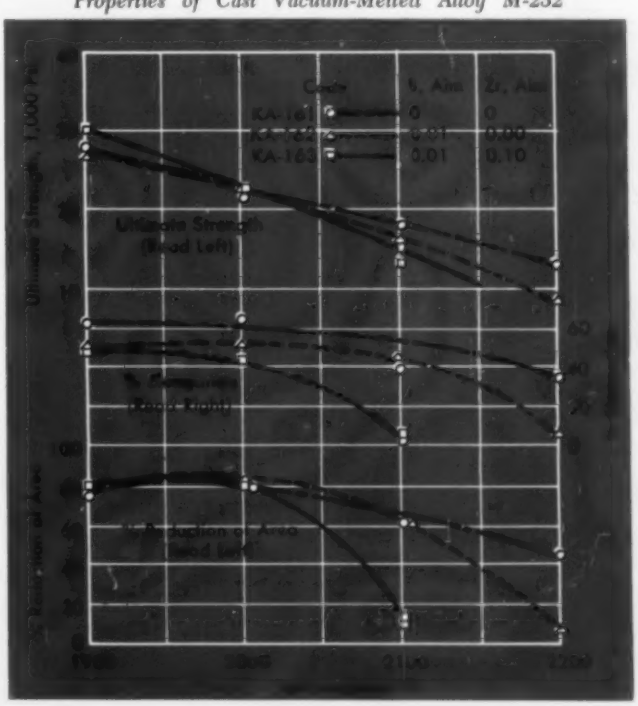


Table II – Schedules for High-Temperature Tests

Grade	Solution Treatment	Aging Treatment	Creep Rupture Stress	Creep Rupture Temperature	Tensile Test Temperature
M-252	4 hr. at 1950° F.	15 hr. at 1400° F.	35,000 psi	1500° F.	1350° F.
J-1570	2 hr. at 2150	24 hr. at 1650	20,000	1650	1350
Waspaloy	4 hr. at 1975	24 hr. at 1550, plus 16 hr. at 1400	40,000	1500	1350
Nimonic 90	8 hr. at 1975	16 hr. at 1300	20,160	1600	1500

boron or 0.05 to 0.10% zirconium.

After the second ingot was tapped, the other addition (either boron or zirconium) was added to the balance which was then tapped into two ingots containing both boron and zirconium.

From our previous experience, such additions were known to have a great effect on forging characteristics, and to determine this effect quantitatively the following method was devised: Four tensile specimens were machined from small as-cast samples, and tested at 1900, 2000, 2100 and 2200° F. at a nominal strain rate of 8 in. per in. per min. Tensile elongation and reduction of area were then correlated with test temperature; Fig. 1 is an example for M-252, from which the forging temperature of 2050° F. was selected for KA-163 (M-252 with 0.01% B and 0.10% Zr). Using forging temperatures determined in this manner, ingots were forged to 4-in. square billets and subsequently hot rolled to ⅝-in. rounds. While no attempt will be made to present the specific practices for each grade, each ingot was fabricated using optimum procedures for each alloy.

Specimens from the ⅝-in .bar. stock of each heat were solution-treated and rough machined to 0.335 in. in diameter. Final machining was into test pieces with 0.160-in. reduced section, 1 in. between fillets at the shoulders. Both smooth specimens and notched specimens were made. The latter had a 60° V at mid-length, 0.024 in. deep, and 0.005-in. radius at bottom. Specimens were then aged, and ground and polished to final size. Creep-rupture and elevated-temperature tensile tests were run on the schedule shown in Table II.

Air Melting

Normal practices for melting in air have been known to produce high-quality A-286; however, susceptibility to notch brittleness, along with large amounts of scatter, has caused the rejection of many heats. Careful evaluation of these rejected heats failed to find the real cause, and it was concluded that the trouble resulted from a summation of minor effects detrimental to mechanical properties at elevated temperatures.

A comprehensive study of the many variables, undertaken by the quality control group at Universal-Cyclops Steel Corp., discovered that very small amounts of boron were required to meet existing specifications, particularly as to high-temperature notched rupture strength. Consequently a series of 13 air-electric arc furnace heats of A-286 were made, the first six without any boron, and the remaining seven heats with intentional boron additions ranging from 0.0037

Table III – Average Improvement Factors for M-252, J-1570, Waspaloy and Nimonic 90

Property	Boron *(a)*	Zirconium *(b)*	B+Zr *(c)*
Minimum creep rate★ *(d)*	1.19	3.02	3.48
Rupture life† *(d)*	1.69	2.20	3.87
Rupture elongation† *(d)*	1.58	1.27	2.27
0.2% yield strength† *(e)*	0.97	1.04	1.01
Tensile strength† *(e)*	1.00	1.01	1.01
Tensile elongation† *(e)*	1.36	0.99	1.36

(a) 0.005 or 0.01% B
(b) 0.05 or 0.10% Zr
(c) Any combination of (*a*) and (*b*)
(d) Testing conditions noted on Fig. 2 and 3
(e) Short-time high-temperature test at 1350 or 1500° F.

★Improvement factor for minimum creep rate = (Value for control alloy)÷(Value for alloy containing B or Zr)
†Improvement factor = (Value for alloy containing B or Zr)÷(Value for control alloy)

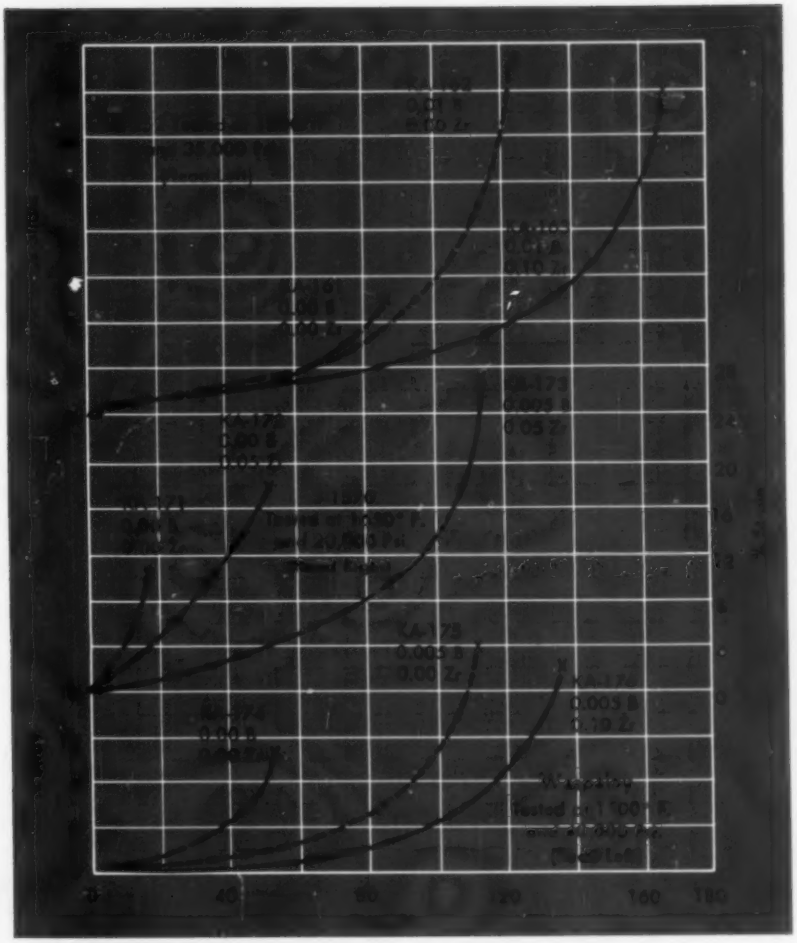


Fig. 2 – Effect of Boron and Zirconium on Creep Characteristics of Vacuum-Melted M-252 (Top), J-1570 (Middle) and Wasapaloy (Bottom)

to 0.009%. Ingots from these heats were forged and hot rolled to 1.375-in. squares in the normal way.*

Since notch-brittle characteristics are of paramount importance, stress-rupture tests were made on plain bars and on notched bars machined from these squares. All were conducted at 1200° F. under a stress of 62,500 psi.

Since the boron in the heats under investi-

*See Table I for nominal composition of A-286.

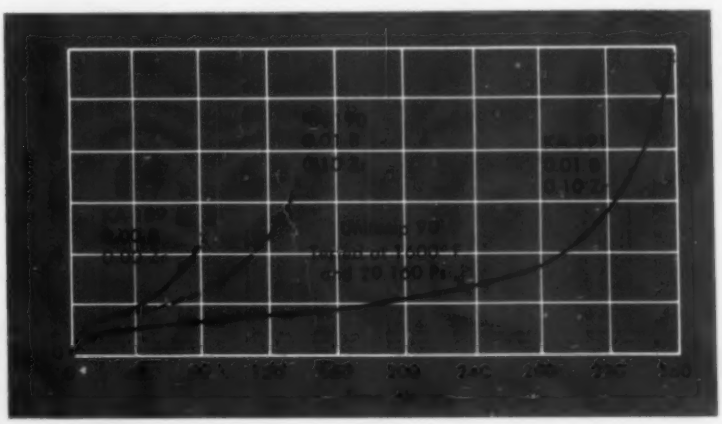


Fig. 3 – Effect of Boron and Zirconium on Creep Characteristics of Vacuum-Melted Nimonic 90. Note difference in horizontal scale between Fig. 2 and Fig. 3

gation is present in quite small percentages, a method was devised to insure accurate and reproducible determinations in these alloys. This method, as developed by Universal-Cyclops Steel Corp., utilizes the characteristic rose color of boron-curcumin complex. The boron is first isolated by distillation as methyl borate after previous solution with mineral acids and subsequent sodium carbonate fusion of insoluble residues. The determination is completed colorimetrically by photometry. This method has proved to be rapid and accurate in determining exact boron concentrations of the magnitude studied in this investigation. A detailed description is available upon request to E. E. Hall, Titusville plant, Universal-Cyclops Steel Corp., Titusville, Pa.

Discussion of Results

Creep curves on the metal described above are given in Fig. 2 and 3, and demonstrate that both boron and zirconium additions in the ranges investigated are beneficial to elevated-temperature properties as measured by creep rate, rupture life and rupture elongation. Moreover, boron and zirconium in combination are more potent together than either element by itself.

The data compiled in Table III illustrate this effect more clearly. It presents average improvement factors for rupture life, elongation, yield strength and tensile strength by calculating the ratio of these properties for alloys with boron or zirconium to those without either element. The improvement factor for minimum creep rate is the ratio of this property for each alloy *without* boron or zirconium to that of the alloys *with* boron or zirconium. An improvement factor of two for rupture life, for example, indicates that the rupture life has been doubled; an improvement factor of two for the minimum creep rate indicates that the creep rate has been halved. Neither boron nor zirconium has much effect on tensile strength at high temperature but the tensile ductility is increased.

Small amounts of either boron or zirconium also have an appreciable effect on forgeability of each of the nickel-base and cobalt-base alloys investigated. The ultimate strength and the ductility of as-cast metal were plotted as a function of test temperature in figures similar to Fig. 1. Reviewing these curves, we note that the ultimate tensile strength is not significantly changed by variations in boron and zirconium; on the other hand, the tensile ductility at temperatures between 1900 and 2200° F. may be greatly affected by small boron and zirconium additions. In general, as the total (boron plus zirconium) is increased the temperature at which maximum ductility occurs is successively decreased; therefore, to obtain optimum forgeability the forging temperature must also be decreased. The tensile ductility for as-cast Nimonic 90 containing both boron and zirconium has a sharp maximum at approximately 2000° F., thereby illustrating the narrow forging range for this particular heat.

The effect of small boron additions on rupture life of the notched bar and plain bar was studied statistically for alloy A-286. It became apparent that the main effect of boron (in the levels studied) is to increase the notched-bar rupture life at 1200° F. and 62,500 psi., as clearly shown in the following data:

	Percentile		
	10%	50%	90%
Boron-free heats			
Notched bar	6.5 hr.	64 hr.	109 hr.
Plain bar	30	52	109
Boronized heats			
Notched bar	160	450	1240
Plain bar	42	82	160

This table indicates that notch-brittle tendencies may be observed in heats containing no boron; that is, the probability of a failure at a notch in this material is extremely high since a great majority of the notched-bar tests gave shorter lives than the plain bar tests. On the other hand, there is an extremely small probability of a notch failure in the heats with boron additions, since the average rupture life for the notched bar (50 percentile) is approximately five times greater than the plain-bar rupture life.

Conclusions

It can be seen that small additions of boron and zirconium greatly improve the rupture life and ductility of the vacuum-melted nickel-base and cobalt-base alloys M-252, J-1570, Nimonic 90 and Waspaloy. This improvement varies from grade to grade but is of significant importance in all. Controlled additions of these elements result in over-all increase in the average rupture life from heat to heat.

Small boron additions to the air-melted iron-base austenitic alloy A-286 greatly improve the notched-bar rupture strength, thus minimizing the probability of notch brittleness in these materials. In fact this particular alloy requires boron in order to meet existing specifications.

Descaling of Titanium

By W. B. STEPHENSON, JR.*

A hot solution of sulphuric acid and calcium fluoride, followed by nitric-hydrofluoric acid gives a bright surface, free from pits. Such treatment does not endanger formability. (L12g, Q23q, Q5; Ti)

DURING EARLY WORK with titanium, it developed that the forming and welding of sheet titanium were appreciably affected by the condition of the metal surface. Often it was impossible to shape it without cracking unless it was heated to temperatures which varied from 450 to 1000° F. – the temperature depended on the severity of the draw. Since this heating was done in air, a thin oxide film formed; this film often became a problem during subsequent welding or cold forming operations.

Naturally, the only solution to a difficulty of this sort is to get rid of the film. We began the investigation by determining the type of scale formed at different temperatures; the following table lists the information which resulted:

TEMPERATURE	FILM COLOR	FILM CHARACTER
400° F.	no change	light, tight
600	light gold	tight
750	brown gold	tight
900	purple blue	tight
1000	blue gray	tight
1200	dark gray	loose
1350	gray	flaky

This gave us a rough check on the temperature that had been used to heat treat different parts. The next step was to try various methods of pickling. A molten salt bath was available; however, it became effective for descaling only at temperatures above 1000° F. Since titanium burns quite readily at that temperature, this method is hardly practical. The familiar nitric-hydrofluoric pickling bath was also tried but it often left the surface pitted and rough as Fig. 1 illustrates. Further experimental work developed a solution of sulphuric acid and calcium fluoride which, when hot, converted the scale to a gray film that could be removed by a short immersion in a hot mineral acid bath, preferably a combination of 10% nitric acid with 2% hydrofluoric acid. Since the resulting surface was bright and smooth (Fig. 2), further work was performed to determine the welding and shaping characteristics of the sheet.

Welding tests began with the measurement of

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the surface resistance of the titanium sheet – it varied between 180 and 800 microhms.

A series of panels was then heated at 1000° F. for 1 hr. in an oxidizing atmosphere, producing a thin tight bluish-gray scale with a surface resistance of 12,500 to 25,000 microhms. These panels were immersed in the H_2SO_4-CaF_2 mixture for 5 min., rinsed, pickled in HNO_3-HF for 2 min., rinsed, and blown dry. Resulting surfaces were smooth and bright; they had a surface resistance of 80 to 210 microhms. Figure 3 illustrates the appearance of the various surfaces, before, during, and after treatment.

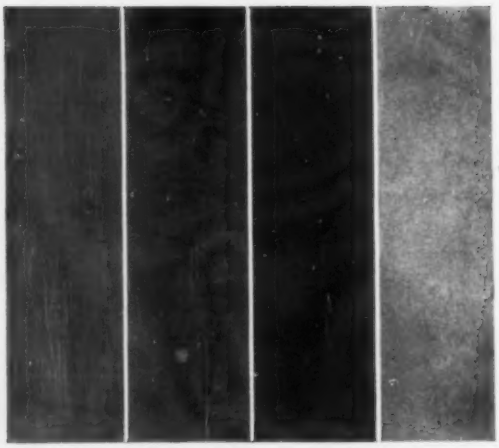


Fig. 3 – Sheet Titanium Strips, From Left to Right, As-Received, Heated to Form Thin Scale, Treated in H_2SO_4-CaF_2 Solution, and Treated in HNO_3-HF Solution. The latter surface is bright and free from pitting

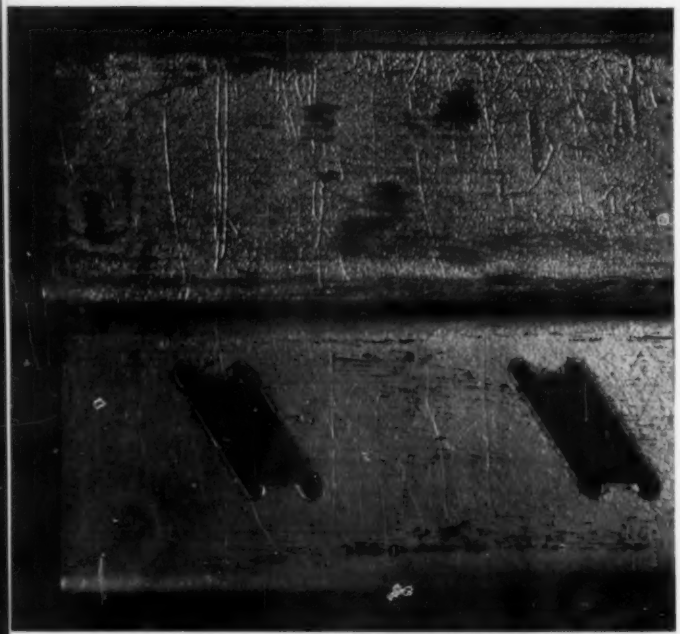


Fig. 1 – Titanium Strip pickled in HNO_3-HF Solution. Note the roughened, pitted surface

Fig. 2 – Titanium Treated in H_2SO_4-CaF_2 Solution and HNO_3-HF solution. A smooth surface is produced

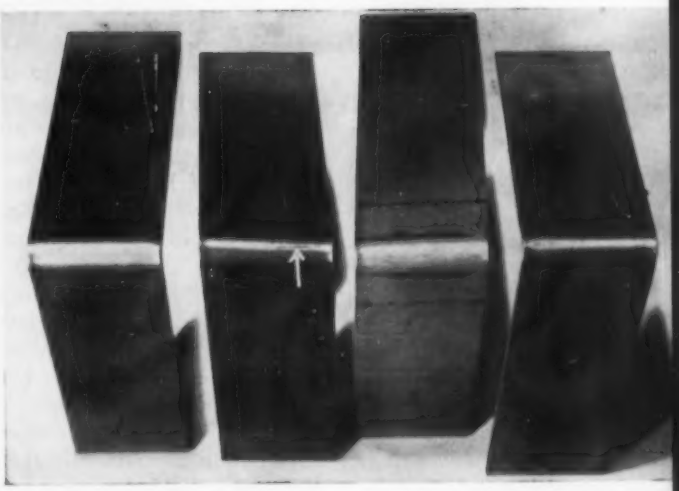
Three sets of peel specimens and one tensile specimen made from "as-received" sheet were spot welded, as were three tensile specimens and seven peel specimens from the pickled panels. These specimens were peel tested; all spot welds on the pickled panels were good. Titanium strips overlapped 1 in. and spot welded once provided the tensile tests. They also proved the pickling treatment to be effective; the strength rose from 2180 lb. to an average of 2740 lb.

Surface loss from the acid treatment was limited; 5-min. immersions in the H_2SO_4-CaF_2 solution resulted in a surface loss of 0.00015 in. while similar times in the HNO_3-HF bath caused a surface loss of 0.0006 in.

The fact that titanium sheet is also deep drawn means that the ability of this pickling method to produce material which welds satisfactorily is not the only criterion. Factors such as hydrogen embrittlement and stress-corrosion, since they affect the formability, must also be considered. Hence, bend tests were run. In only one case did any of them fail – specimens heated but not pickled cracked in the V-block test. This effect is pictured by Fig. 4 along with typical specimens in the as-received condition and after each of the two acid treatments.

Some observers have reported that titanium which had shown no cracks immediately after bending did exhibit cracks several days after bending. Therefore, specimens were checked

Fig. 4 – These V-Block Bend Tests Are Treated in the Same Manner as Those Shown in Fig. 3. Cracking is apparent only in the strip which was heated to form a thin scale; the subsequent descaling operations removed this deficiency



again after two months' storage at room temperature; no cracks had developed during this period.

To check the possibility of stress-corrosion, strips of titanium sheet in the as-received condition were stressed to a calculated 30,000 psi. in a jig and processed (while still stressed) in each of the pickling solutions. Inspection at 20× revealed no sign of corrosion or cracking. With the thought that microscopic intergranular corrosion might have occurred, however, these same specimens were also examined at 1000×; again, no corrosion appeared.

As a final test, the hydrogen content of the titanium strips (in each condition – as-received, heated, and pickled) was determined by the vacuum fusion method. It varied between 223 and 248 ppm. Since this spread is within the experimental error of the equipment used by us, we feel there is no evidence of hydrogen pickup during the acid treatments.

Thus, all of our tests on formed titanium sheet cleaned by this two-solution descaling method proved it to be entirely adequate for any of our subsequent processing.

What's Happened to Cermets?

By J. W. GRAHAM
*and W. F. ZIMMERMAN**

Originally intended for jet engine parts, cermets have become useful in other fields. Their resistance to corrosive liquid metals and acids makes them valuable for pump seals in rockets and nuclear plants. (Q general, T2p, T11, 17-57; 6-70)

CERMETS HAVE HAD a fascinating history. As with shell molding and tape recording, the original work was done by the Germans during World War II. During investigations on the practical aspects of aircraft jet engines, they realized that they needed a material which would have the strength of a metal as well as the heat resistance of a ceramic. The obvious solution being to combine the two, they devised a mixture of iron and aluminum oxide of unusual strength and thermal shock resistance. Soon after the war, technologists in the U.S. Air Force recognized that considerable work was war-

*General Electric Co., Aircraft Gas Turbine Division, Evendale, Ohio. A second article on cermets in jet engines will be published in a future issue.

ranted on metal-ceramic combinations. The word "cermet" was applied to such compositions with the feeling that these materials would have the advantages of both constituents.

Research on oxide-base cermets was begun at the ceramic department of Rutgers, Ohio State University, and University of Illinois; they investigated, respectively, MgO-TiN-Ni, Al_2O_3-Cr, and BeO-Be-Co mixtures. A group at Ohio State University, in fact, made notable accomplishments in Al_2O_3-Cr combinations after studying favorable processing and bonding relationships between a wider group of materials. Similar combinations of Al_2O_3-Cr were also devised by the Union Carbide and Carbon Corp.

As time went on, more and more people began to see possibilities in cermets. By the late 1940's, carbide tool manufacturers were using powder metallurgy processes in their work on new compositions for jet engine components based on titanium carbide. The carbide cermets were being studied in England by Trent, Carter and Bateman who developed TiC-CrC-Ni combinations. Also, Richard Kieffer was working in Reutte, Austria, at the Metallwerke Plansee on titanium carbide combinations with refractory nickel-base corrosion resistant alloys.

In this country, Kennametal Inc., Firth Sterling Co., Sintercast Corp. (with Thompson Products Co.), American Electrometals Inc., and Eaton Manufacturing Co. all contributed considerably to cermet development, each being concerned with its own proprietary processing or compositions. With the many new techniques required for the production of cermet parts as well as in their laboratory and engine test evaluation, a broad base of technical talent was marshalled to make the high-temperature characteristies of cermets available and usable.

Properties

The oxide-base cermets were quite naturally expected to be most suitable for resisting oxidation. An intensive study of this group at Ohio State University showed that Al_2O_3 bonded by chromium possessed satisfactory resistance for long periods up to 2200° F. and for shorter periods even to 2750° F.

Several other approaches to oxidation resistance were tried. Using titanium carbide as a base, compositions were developed with chromium – either as an alloying agent with the ferrous group metals or as a carbide additive. Other additions tried were corrosion resistant alloys (generally high in chromium), glass

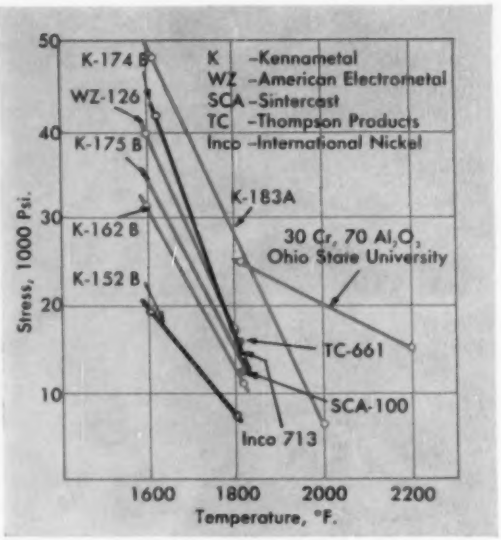


Fig. 1 – Stress-Rupture Curves for Various Cermets; 100-Hr. Duration

formers such as boron or silicon, and the columbium-tantalum carbides. All were successful in increasing the oxidation resistance of cermets based on TiC, especially between 1400 and 2000° F. Personnel of Ohio State University who studied the oxidation phenomena concluded that, as in alloys, oxidation resistance was related to the electrical characteristics of the coating.

Intensive research was also aimed at improving the other important cermet properties, including stress-rupture, ductility, fatigue and impact resistance. Further improvements in stress-rupture have lately been announced: Kennametal, for instance, has a TiC base cermet which withstands 28,000 psi. at 1800° F. for 100 hr. Figure 1 summarizes these data along with the properties of several other cermets. The testing which has been done shows that the elongation rises and the strength drops as the temperature gets higher. To date, the greatest amount of ductility reported was 3% elongation at 1600° F. for a cermet with high metal content. This is quite low in comparison to the 30 to 60% elongation reported for some superalloys at this temperature. Also indicated, of course, is the usefulness of cermets in applications where resistance to deformation under comparative stress conditions is a primary factor. Typical tensile test curves are illustrated by Fig. 2.

While some of the strongest TiC cermets resist 75,000 psi. when tested for fatigue at room temperature, the curves are rather flat because

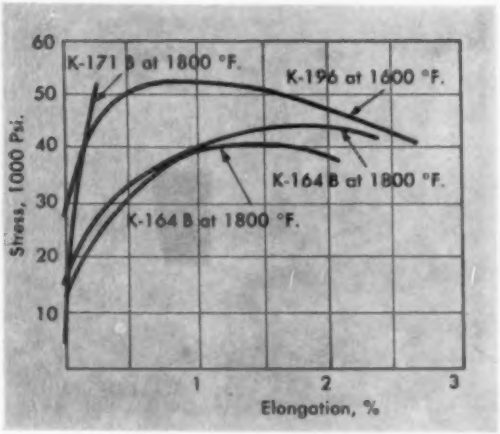


Fig. 2 — Typical Tensile Test Curves at Elevated Temperatures. The curves for K-164 B each represent an individual test.

cermets cannot resist significantly higher strength for short periods. In general, however, the cermets have better unnotched fatigue strength than the superalloys.

Impact Resistance

Even though most of the properties needed for turbine bucket operation were obtained to a satisfactory point, low impact resistance remained to restrict the application of cermets in jet engines. Since impact resistance is so important, much effort was made to improve and evaluate this characteristic.

Room-temperature impact values measured on unnotched Charpy-type specimens were 5 to 10 ft-lb. as compared with values of 50 ft-lb. for existing turbine bucket alloys. To approach typical bucket cross sections, smaller impact specimens were devised and impact resistance was measured in testing equipment modified from those designed for plastics. Results were reported as in-lb.

When many groups became involved in the impact testing of cermets, considerable variations in test results were reported. To understand the reasons for this, Wright Air Development Center sponsored a detailed study of test methods at Alfred University, where it was found that any standardized test should be able to measure comparative and minute variations. A precise falling weight method, which received industry-wide acceptance, was the result. This test can determine small differences between various cermet grades; however, it developed that significant compositional changes did not improve impact resistance appreciably. For example, the average range of impact resistance remained about one tenth that of such alloys as X-40*. Consequently, renewed creative activity was necessary to eliminate this obstacle.

One approach tried by the Sintercast Corp. succeeded in raising the impact strength by metallic infiltration of semi-sintered TiC skeletons. This produced a continuous ductile metallic structure with the carbide phase distributed as discrete particles.

Applications

While the cermets have never become usable in the jet engine applications for which they were originally intended, they have developed into an extremely useful material for other parts. For example, they have been used where corrosion resistance is essential. Zirconium boride cermets are not attacked by molten aluminum and they have been used for thermocouple tubes. Centrifuge scrapers in salt solution are another application for corrosion resistance.

In nuclear energy applications for such items as fuel elements, control rods, bearings and seals in alkali-metal heat transfer media, the unique characteristics of cermets have made them extremely useful, particularly when modified to meet the demands of specific applications.

Systems for handling liquid fuels for rocket propulsion have made use of the extreme hardness, wear resistance, corrosion resistance, and low thermal expansion of cermets — especially in seals at necessary joints or glands. In pumps for liquid oxygen, hydrocarbons and fuming nitric acid, these characteristics are essential. Excellent possibilities also exist for cermets in rocket combustion chambers and missile components. Other possible uses are as dies for ceramics, pressing, coining and extrusion of glasses, special valves, and autoclaves for chemicals; in all of these, the temperature-resistant properties of cermets are valuable.

Cermets will undoubtedly be more widely applied in the future. As of the moment, however, the design engineer lacks sufficient knowledge of their properties, while the cermet development engineer is not familiar with specific industrial areas in which cermets can be applied. Future cooperation between design and development engineers will probably create unique materials for specific applications.

*A good, and early, "superalloy" of cobalt, containing 28% Cr, 12% Ni and 7.5% W.

Iron Powder Made by the H-Iron Process

*By JEROME F. KUZMICK and KENNETH W. BRULAND**

Magnetite concentrate of high purity is reduced by hydrogen (97% purity) at 400 psi. and 1000° F., and reheated in protective gas to 1500° F. to prevent reoxidation. Hydrogen is made from coke oven gas. Various grades of iron powder are suitable for molding, for a chemical reagent, and for high-grade melting stock. (H10c; Fe)

THE ALAN WOOD STEEL CO. has been interested in iron powder for a number of years because it has available a raw material uniquely suited for its manufacture. Since 1929, the company has operated its Scrub Oaks Mine in Dover, N.J., which is the largest known magnetite iron deposit in that state, mining approximately 3500 tons per day. The ore contains 28% iron; it is crushed to ⅛-in. lumps, and the magnetite removed from the gangue by magnetic separators. (Since the ore contains some hematite, a gravity system of concentration is also used.) The main product is known as "regular grade concentrate", analyzes about 67% iron, and goes to the company's blast furnaces at the steel works in Conshohocken, Pa.

During recent years, the company has been interested in the development of special products. The mining division studied the properties of the ore to develop grades of magnetite suitable for other applications. The regular grade concentrate was found to contain a large proportion of particles smaller than 30 mesh which were free, or nearly free, of impurities. Separation of these particles by gravity resulted in a product containing over 71% iron which is marketed as "high-grade concentrate" and has been accepted for application in many chemical processes.

Further study of this high-grade concentrate indicated that the remaining impurities were finely disseminated throughout the ore. Upon ball milling to pass through a 100-mesh screen, most of these impurities were freed and could then be eliminated by a magnetic separator. In this way a concentrate of about 99.7% Fe_3O_4, containing over 72% iron, was produced and became known as "super high-grade concentrate". Analyses of each are given in Table I, and it can be seen that the silica has been reduced to 0.17% and other insolubles reduced to 0.10% in the super high-grade concentrate.

About six years ago, a research program was started at Alan Wood Steel Co. on a process for manufacturing high-quality iron powder from the high-grade and super high-grade concentrates. Many methods of reducing iron oxide by carbon and hydrogen were studied. It seemed undesirable to copy some other process, and desirable to stick to a high-temperature reduction method. At no time was consideration given to the so-called fluid bed methods of reduction because of several failures in previous attempts by other investigators, usually due to the reduced iron sticking to itself and to the

* Mr. Kuzmick is consultant to Alan Wood Steel Co., and Mr. Bruland is superintendent of the iron powder plant. This article is from a paper presented at a Symposium on Powder Metallurgy, held jointly by the Metal Powder Association and the American Society for Metals, Chicago, Nov. 7, 1957.

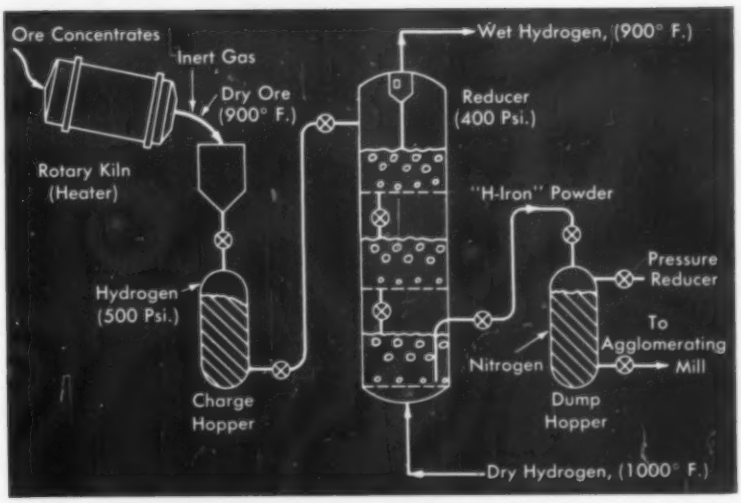


Fig. 1 — Flow Sheet of H-Iron Process

walls of the reducing chamber, finally jamming the whole apparatus.

After about two years of such work a high-temperature reduction method was developed which looked very promising and produced high-quality iron powder. Construction of a pilot plant was authorized and patent rights were later received for the method.* The pilot plant, which had a capacity of about one ton per day, was in successful operation by late 1955. The quality was excellent, and many tons were successfully used in consumers' plants. In March 1956, $2,250,000 was appropriated for a plant to produce 25 tons of iron powder per day, based on this process. Just as engineering work was started, the company learned of the "H-iron" process developed by the Hydrocarbon Research Corp. in cooperation with Bethlehem Steel Co. Supposedly this produced iron at a cost sufficiently low to warrant its consideration as a scrap substitute, so work on the original plant was suspended while an investigation could be made.

The H-iron process uses a "fluid bed" to reduce iron oxide particles to iron powder. The shortcomings of previous attempts to utilize such methods were overcome in work done by the Hydrocarbon Research Corp. in the petroleum field, and demonstrated by a plant at Brownsville, Tex., which was successfully operated for three years, producing about 20 tons of iron powder per day used as a catalyst in a synthetic gasoline plant.

The success of the H-iron process depends upon several factors, including an economical source of high-purity hydrogen, ability to transport particles by a gaseous medium from one container to another, and reduction of iron oxide at sufficiently high pressure and low temperature that sintering of the particles to themselves or to the container is avoided.

Figure 1 is a flow sheet. The ore concentrate is preheated in a rotary kiln to about 900° F., transported by inert gas to a charge hopper into which hydrogen is then introduced and built up to a pressure of about 500 psi. — 100 psi. higher than the pressure in the reactor. As required, the ore from the charge hopper is transported through pipes and valves into the reducer by "dense phase transport", which means that, at the pressure differential involved, the particles in their packed density can be forced to flow through pipes into a chamber at lower pressure. The method was first successfully demonstrated by the U. S. Bureau of Standards in the transport of coal particles.

In the reducer, the oxide is converted to metal in three separate beds. Initial reduction takes place in the upper bed, intermediate reduction

Table I — Analyses of Raw Materials

Component	Ore	Concentrates		
		Regular	High-Grade	Super High-Grade
Iron	28	67	71.3	72.0
Silica	45	5.5	0.6	0.17
Other insolubles	14	1.3	0.2	0.10
Phosphorus	0.05	0.015	0.006	Trace
Sulphur	0.03	0.010	0.004	Trace

*U.S. Patent No. 325,104.

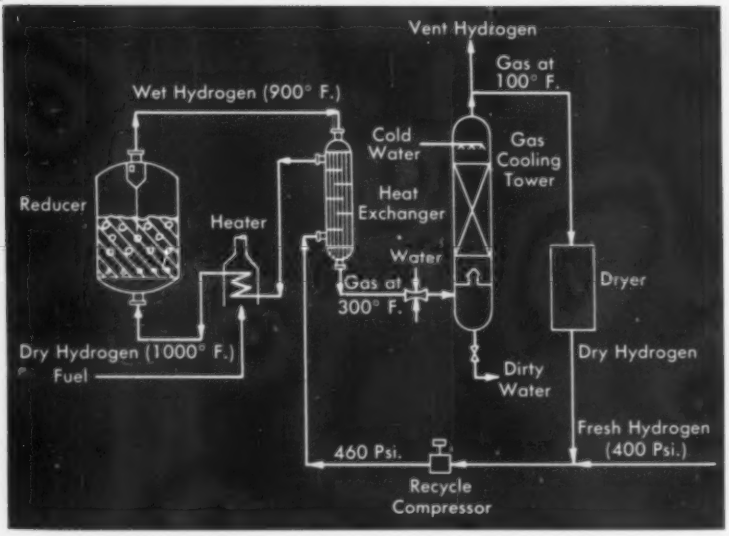


Fig. 2 – Flow Sheet of Hydrogen Recirculation and Make-Up System

in the center bed, and final reduction in the bottom bed. Dry hydrogen of about 97% purity, at a temperature of 1000° F., is introduced into the bottom of the reactor at a pressure of 400 psi., and at velocity sufficient to maintain the iron particles in suspension on each bed. The result is a "fluid bed" process. As the hot hydrogen is circulated around and between the particles, the oxide is reduced to metallic iron. Water is the other reaction product. The wet hydrogen issuing from the top of the reactor is then purified, dried and recirculated in the process (together with make-up hydrogen).

Division of the reduction into three beds results in greater efficiency. At particular periods the ore is moved downward from bed to bed and is completely reduced in the bottom bed. The iron powder is then transported through piping and valves to a dump hopper. In this hopper the hydrogen pressure is brought down to standard atmospheric pressure and the hydrogen is then removed by flushing the hopper with nitrogen. Finally, the reduced iron particles are removed from the dump hopper for further processing.

All of the reduction is at temperatures below 1000° F.; consequently no sintering occurs. As a matter of fact, the particle size of the reduced iron is just about the same as the particle size of the iron ore concentrate used as raw material.

Either magnetite (Fe_3O_4) or hematite (Fe_2O_3) fines can be reduced in this manner; 100-mesh particles are about two thirds reduced in two hours. From then on the magnetite is reduced more rapidly; about 95% of its oxygen is removed in a total of 4 hr. whereas hematite requires about 8 hr. for equal reduction.

Figure 2 is a flow sheet showing the apparatus for recycling of the hydrogen. The wet hydrogen leaving the reducer is put through a heat exchanger where it helps preheat incoming fresh hydrogen. The wet hydrogen (now at about 300° F.) is then put through a cooling tower where most of the water condenses. Some of the hydrogen is then vented in order to keep down the proportion of nitrogen in the cycle, as some nitrogen is present in the original hydrogen and some enters with the raw concentrates. The hydrogen may be further dried, if desired, and it is then added to make-up hydrogen coming in from the gas manufacturing plant, after which it is compressed to the working pressure, 460 psi. From the compressor, it goes through the heat exchanger and then a furnace to bring it up to 1000° F., at which temperature it is introduced into the reducer.

In investigating this process, the Alan Wood Steel Co. arranged to have several tons of its high-grade and super high-grade concentrate reduced in a pilot reactor at the Hydrocarbon Research Laboratory in Trenton, N.J. (A photograph of this reactor prior to its being covered with insulation is shown in Fig. 3.) It was found that both grades could be successfully reduced (95% of the oxygen removed).

The resulting powder, however, was extremely pyrophoric and had to be kept in an inert atmosphere. Its apparent density was very low and it had poor flow characteristics so that it was not readily adaptable to powder metallurgical

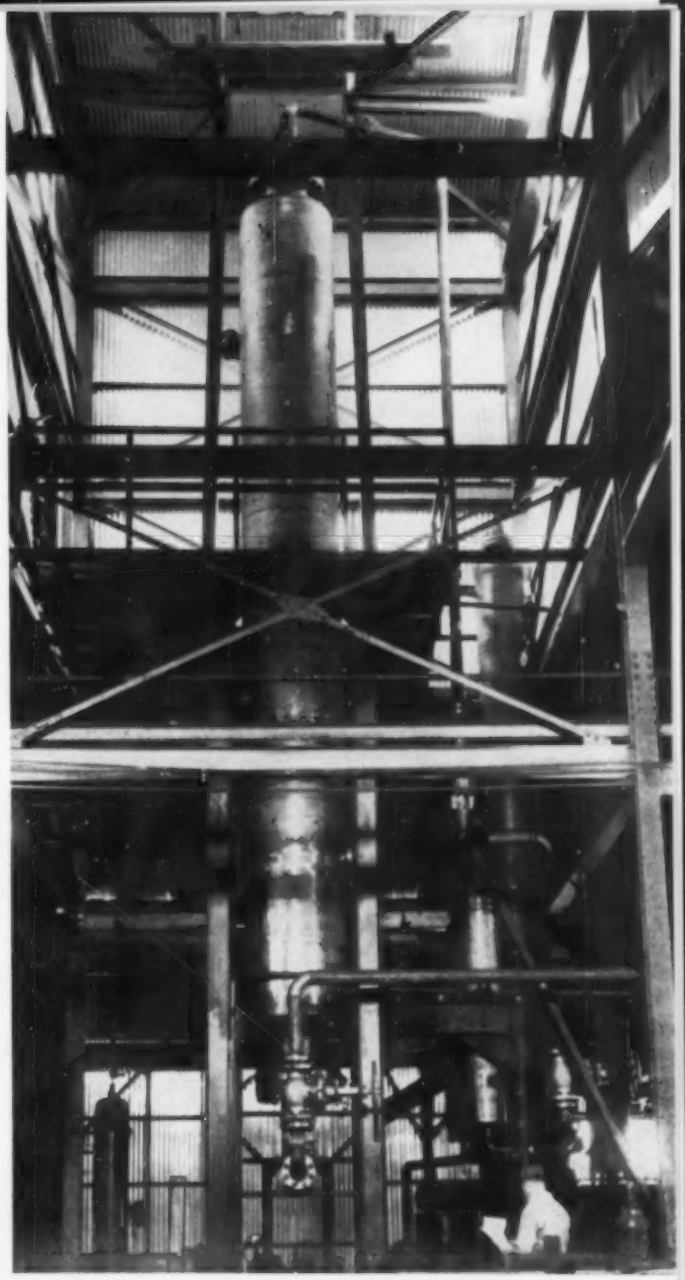


Fig. 3 – Pilot Reactor (Reducer) Before Being Covered by Insulation

uses. It was then found that, if the iron powder were heated to several hundred degrees above the reduction temperature in protective gas at atmospheric pressure, the iron powder was no longer pyrophoric. Methods were then developed for densifying and otherwise treating the iron powder as required for various applications. As a result, several grades of iron powder have been successfully tested by customers.

Analysis of nonmolding iron powder produced from high-grade concentrate and suitable for such applications as flame cutting and welding rod flux is as follows: Iron 98.0%, hydrogen loss 0.80%, SiO_2 0.85%, P 0.008%, S 0.005%, C nil. It has been produced in a coarse and fine size as shown by the following screen analyses:

	Coarse	Fine
Apparent density	2.7	2.8
Flow	–	25 sec.
Sieve analysis		
+30	0.0	–
− 30 +80	40	–
− 80 +100	17	0.0
−100 +200	35	30
−200 +325	6	30
−325	2	40

Figure 4 shows photomicrographs of these nonmolding powders.

Iron powder for molding into compacts is produced from super high-grade concentrate, and is of quite high purity. Its analysis is iron 98.5%, hydrogen loss 0.5%, silica 0.2%, carbon nil, and only traces of phosphorus and sulphur. Physical properties of a low-density molding powder suitable for friction materials and of a powder of standard density suitable for molding machine parts are as follows:

Fig. 4 – Micrographs of Coarse Nonmolding Iron Powder (Left) and Fine (Right) at 60 ×

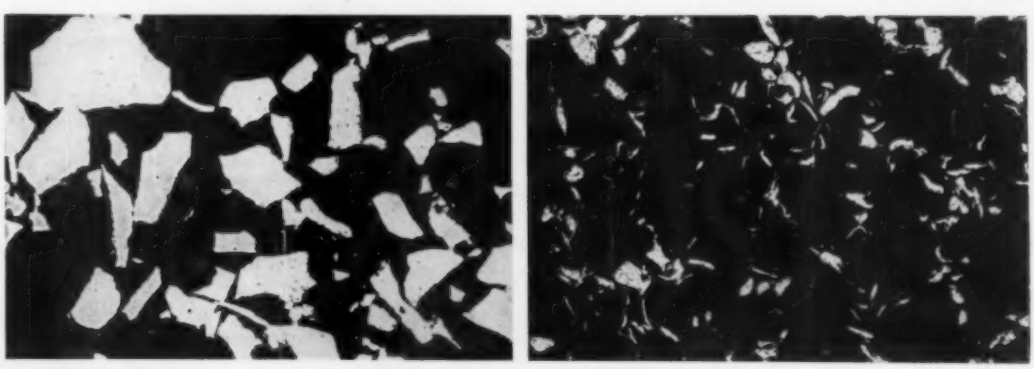


Table II – Molding and Sintering Properties

Mixture	Apparent Density	Green		Sintered Compact			
		Density	Strength	Strength	Elong.	Hardness	Dimensional Change
100 Fe, 0.75 Zn St.	2.59	6.36	2230 psi.	26,970 psi.	10%	—	−0.30%
99 Fe, 1 C, 0.75 Zn St.	2.58	6.31	1950	48,130	3	B-41 to 49	0.0
92.5 Fe, 7.5 Cu, 0.75 Zn St.	2.61	6.45	2230	52,690	3	B-43 to 52	+0.10
92 Fe, 7 Cu, 1 C, 0.75 Zn St.	2.57	6.39	1970	74,380	1.5	B-74 to 82	+0.20

	Low Density	Standard Density
Apparent density	1.6	2.3
Flow	35 sec.	30 sec.
Sieve analysis		
+80	0.0	0.0
− 80 +100	5	1
−100 +200	35	30
−200 +325	30	35
−325	30	35

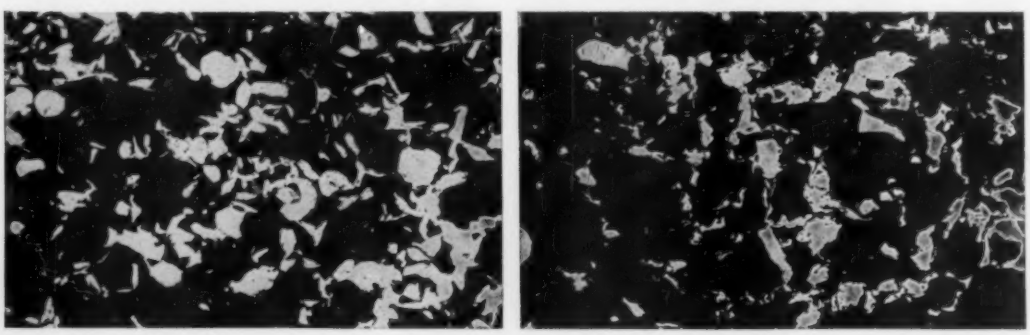
The photomicrographs in Fig. 5 show that the particles are irregular in shape and are very clean and free from unreduced oxide inclusions. (Particles are mounted in bakelite. Density refers to particles themselves rather than the mass.)

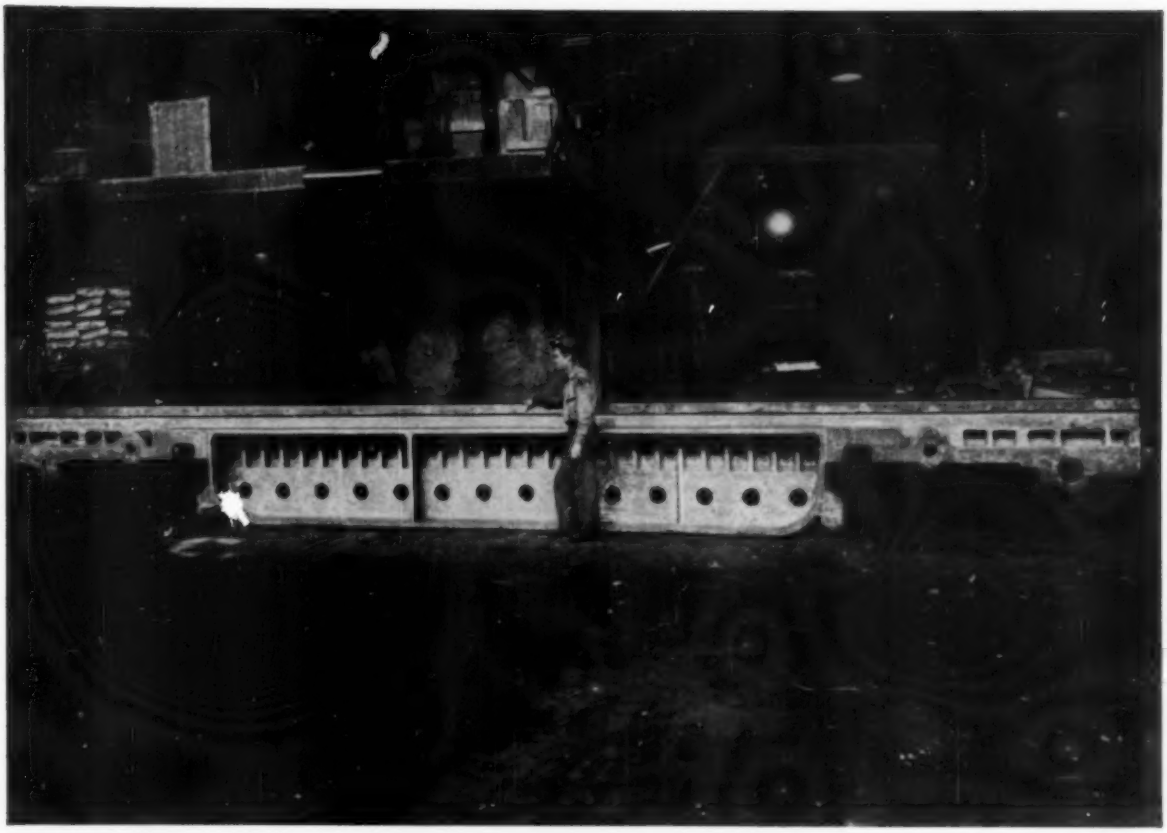
Table II shows the properties of green and sintered compacts produced from the molding iron powder of standard density. The mixes are commonly used in the powder metallurgy field for iron parts. Some are iron alone with addition of zinc stearate lubricant; others are iron with 1% carbon, iron with 7½% copper, and iron with 7% copper and 1% carbon. All compacts were molded at 30 tons per sq. in. pressure and sintered for 45 min. at 2050° F. in dry hydrogen. Note the excellent green strength and sintered strength of these specimens as well as their good elongation. The dimensional change in diameter is also very small, regardless of the mixture used. Copper-infiltrated iron compacts made from this powder undergo practically no dimensional change during infiltration. Such a powder should be welcomed by designers of dies for powder metal parts, since very little allowance for shrinkage or growth need be made.

As a result of the successful development of these iron powders based on the H-iron process, the Alan Wood Steel Co. is designing a plant to produce 50 tons of iron powder per day. This plant will use hydrogen manufactured by the partial oxidation of coke oven gas, which is available at the company's steel plant at Conshohocken. The oxygen required in this gas manufacture is also available from a nearby source which currently supplies oxygen to the company for its steelmaking operations.

Because of the availability of inexpensive raw material, as well as gas for atmosphere and fuel, a cost survey indicates that iron powder can be produced very efficiently at low cost. As operations get under way, part of the H-iron will be used in the form of pressed briquettes in open-hearth furnaces to study the feasibility of using it as a substitute for scrap. Some may be sold as high-purity iron briquettes, to be used as melting stock for special alloys. The rest will be marketed as iron powder in the powder metal industry.

Fig. 5 – Micrographs of Low-Density (Left) and Standard Density (Right) Powders for Molding Into Compacts. 60 ×





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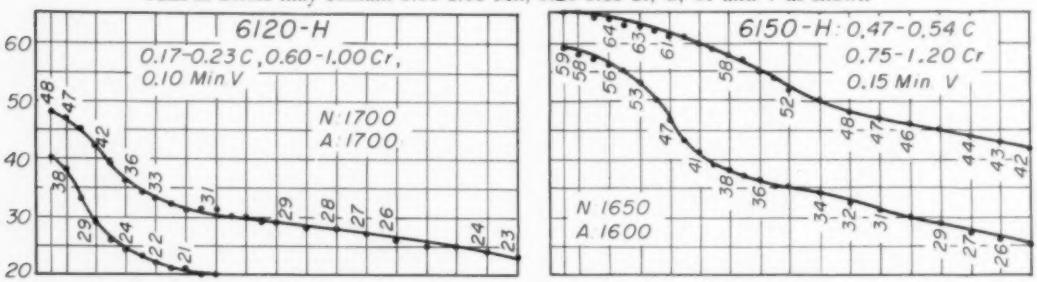
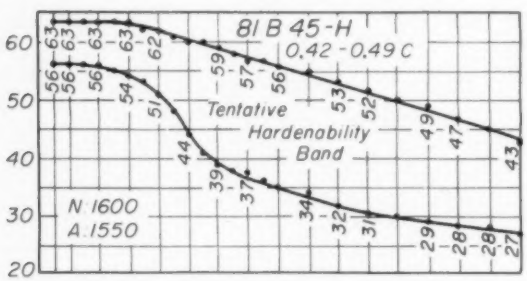
A.I.S.I. List of March 1957

61xx-H Series may contain 0.60-1.00 Mn, 0.20-0.35 Si; C, Cr and V as shown

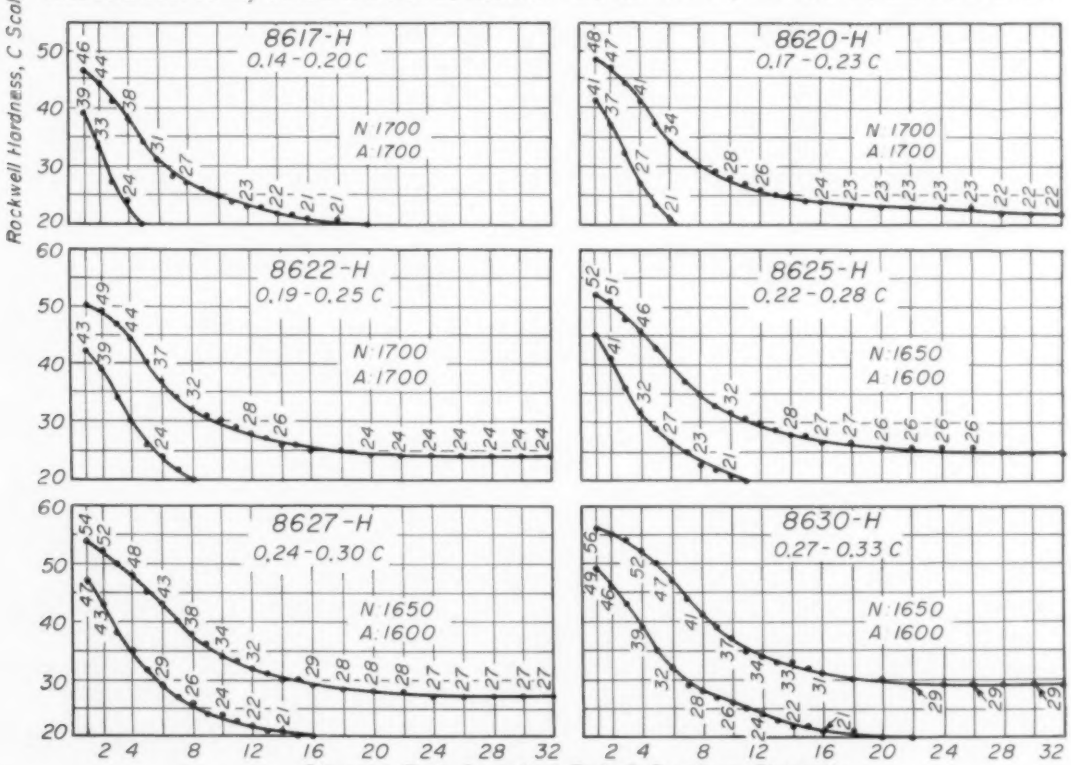


81 B 45-H may contain 0.75-1.05 Mn, 0.20-0.35 Si, 0.15-0.45 Ni, 0.30-0.60 Cr, 0.08-0.15 Mo



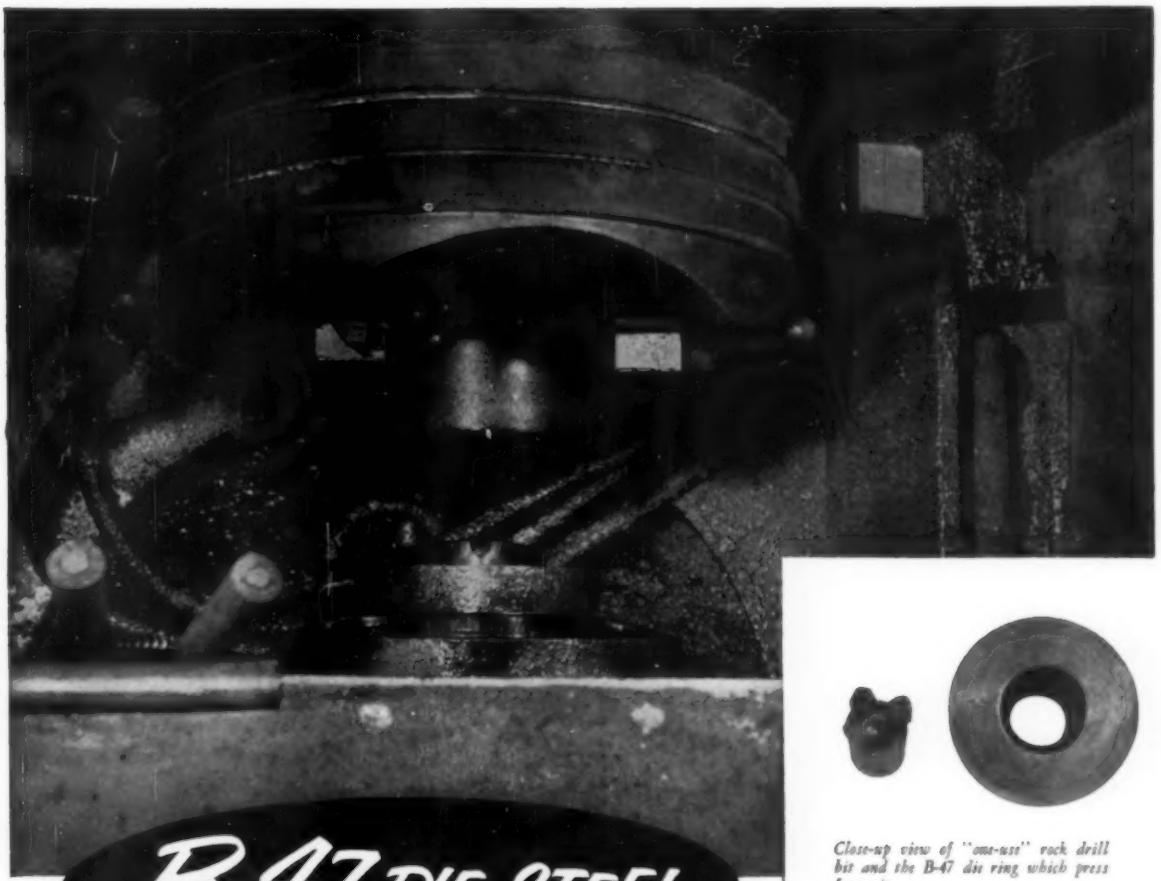
The boron or B-steels can be expected to have 0.0005 min. B

8617-H to 8630-H may contain 0.20-0.35 Si, 0.60-0.95 Mn, 0.35-0.75 Ni, 0.35-0.65 Cr, and 0.15-0.25 Mo



N means normalizing temperature for forged or rolled material; A means austenitizing temperature (both as recommended by S.A.E.).

Hardness limits are specified in Rockwell C-scale units (no fractions) and can be scaled from the plotted points where not labeled at even sixteenths.



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A. Nickel and 47 % Zirconium Alloy

B. Type 405 Stainless Steel Brazed with Ni-Cr-Si Alloy

C. Size and Distribution of Nonmetallic Inclusions in Low-Alloy Steels

D. Carbide Skeleton Formation in a WC Plus 10 % Co Cemented Carbide, as Sintered

E. Commercial Heat of A-286; Overaged Structure and Bierbaum Scratch Hardness Taken in Field of Optical Micro

F. Electron Micrographs of Irradiated Uranium

G. Scale Formed by Corrosion of Chromium in Air at Elevated Temperature

12 HONORABLE MENTION AWARDS

H. Chromium-Carbon Alloy, $Cr_{23}C_6$

I. Type 405 Stainless Steel Brazed with AMS 4775 (Ni-Cr-Si-B-C) Alloy

J. Complex Nonmetallic Inclusion in ML-1700 Alloy (Cobalt Base)

K. Zircaloy-2—Boron, as Polished

L. Zirconium-Gadolinium Oxide

M. Partial Primary Recrystallization in 3¼ % Silicon Iron

N. Triangular Pattern on Bottom of Single Crystal of Silicon Probably Caused by Dislocations

O. Pearlite and Ferrite in 0.25 % Carbon Steel Castings; Contact Prints

P. Wrought Iron Nail of 300 Years Ago

Q. Nickel-Molybdenum-Aluminum Alloy

R. 2¼ Cr, 1 Mo Weld Metal on Carbon Steel Base Metal, Aged 1150 Hr. at 1200° F.

S. Motion of Dislocations During Bending of Lithium Fluoride Crystal

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Stewart S. Smyth
Large Steam Turbine-Generator Department
Schenectady, N. Y.
AWARDS B, I

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AWARD E

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AWARD F

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West Lynn, Mass.
AWARD P

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A High-Strength Cast Steel

By C. G. MICKELSON
and R. D. ENGQUIST*

A low-alloy, Mn-Cr-Mo cast steel with boron and rare earth additives which can be heat treated to tensile strengths above 220,000 psi. possesses excellent ductility and impact properties plus great wear resistance in dipper teeth, chute liners, and tractor shoes.
(T 28, 17-57, Q general; AY, 5-60)

REQUIREMENTS for lightweight rugged equipment have resulted in a search by design engineers for new cast materials. At the present time, there is a definite demand for steels with tensile strengths higher than 200,000 psi. which have good ductility and impact resistance. Even higher strength materials will be desired in the future. Not only is the development of such materials a burden on the metallurgist, but the development of processing techniques and inspection procedures permitting commercial manufacture is also a problem.

Points for dipper teeth with strength, toughness and wear resistance to dig the taconites of Northern Minnesota are an instance. Their properties had to be remarkable; high yield strength is necessary to prevent deformation under load, high hardness is needed to combat the abrasion of the flint-hard ore, and high impact resistance at low temperatures is required to operate in the –50° F. winters of the Mesabi Range. This is quite a lot to ask of any cast steel product.

Drawing on information accumulated from the development and production of cast armor, the manufacturing research laboratory of American Steel Foundries produced a low-alloy cast steel which could meet these requirements.

Many tons of this steel have since been melted and cast into dipper teeth, crusher and chute liners, tractor shoes, and other parts in which strength, toughness and wear resistance were wanted. With the cooperation of many users, service records were obtained; the material turned out to be quite a success.

What sort of a steel is this, anyway? Well, as mentioned previously, it is a low-alloy steel – trade-named "Wearpact" – with a nominal composition of 0.23 to 0.33% C, 1.30 to 1.80% Mn, 0.30 to 0.60% Si, 0.40 to 1.00% Cr, and 0.40 to 0.60% Mo. A small amount of boron is added to increase the hardenability. Additions of rare earth metals result in the formation of globular inclusions. Ductility and resistance to impact are also helped by these additions. Aluminum deoxidation insures a fine grain size; this also adds resistance to impact. Castings of this alloy are heat treated to a tempered martensite.

Composition and Properties

This analysis and structure result in an unusual combination of properties. Tempering of the quenched material to Brinell 500 hardness gives a tensile strength of 240,000 psi. with 10% elongation and 22% reduction of area. The impact values at this strength level are very good (20 ft-lb. at both +80 and –40° F.). At Brinell 400 (after tempering at 700° F.), the temper brittleness appears and the impact values drop to 10 ft-lb. at –40° F. The transition range of the hardened materials is between –175 and –200° F., so low as to virtually preclude the possibility of brittle failure.

Polished fatigue specimens of this steel have an endurance limit of 73,000 psi.; when notched

*Assistant Manager and Senior Research Metallurgist, respectively, American Steel Foundries, East Chicago, Ind.

fatigue specimens are substituted, the figure falls to 53,000. Considering that the Brinell hardness of these specimens was 500, it is apparent that the steel is relatively insensitive to notches. It is also magnetic and hardens well in sections up to 4 in. thick.

Pouring characteristics are essentially the same as any low-carbon constructional steel. Metal fluidity is typical of 0.30% carbon intermediate manganese steels in the normal range of pouring temperatures. The new steel is less susceptible to hot tearing than plain carbon or carbon-manganese steels of equivalent carbon and sulphur content. This is fortunate since incipient hot tears can be very damaging when such a highly hardenable alloy is heat treated. Gradual section changes and broad fillets are necessary to lessen hot tearing difficulties; the problem can be virtually eliminated by the use of good foundry, core and pouring practices.

Fabrication

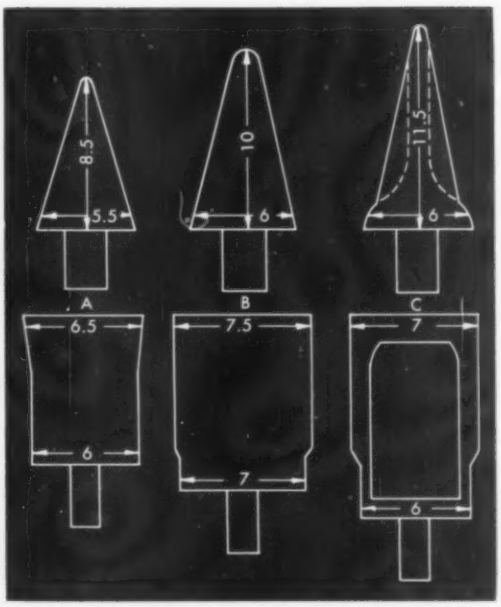
Controlled welding practices and suitable welding electrodes are needed for repair welding and field fabrication of complex structures. Minor welding jobs are permissible after hardening and tempering if they are not in areas of high stress or wear. Such welding (on pieces preheated to 150 to 300° F.) should be done with stainless steel electrodes or low-alloy electrodes (A.W.S.-A.S.T.M. Class E-7016 through E-12015).

The castings can be readily machined in the normalized and tempered condition. However, low cutting speeds are necessary to obtain good die life at a hardness of Brinell 500.

Applications

The taconite ore of the northern Minnesota mines is so hard and abrasive that many normal mining practices are prohibited. For example, blast holes must be drilled with the oxygen-kerosene jet piercer because conventional drills wear at an impossible rate. In competitive tests, the new steel hardened to over Brinell 496, outlasted all others at a rate of 2 to 1 – often 3 to 1. Some of these dipper tooth tests were during the coldest winter months when the temperature dropped as low as −40° F.

Dipper tooth points used in the initial testing program were all of conventional design. After evaluation, it was concluded that the points could be redesigned. The new design was tested and proved satisfactory; however, further modifications were made to obtain even better service life. The new design retains a sharp cutting edge throughout the useful life of the casting. The original design and the two modifications are shown in the drawing.



Original Design of Dipper Tooth With Two Subsequent Modifications. The center design resulted in a longer life; the design on the right illustrates the self-sharpening feature of the third modification

Abrasion resistant parts such as crusher and chute liners have also been tested. The high strength prevents plastic deformation and maintenance problems are lessened; the high hardness also makes the castings very wear resistant.

Grouser and tractor shoes cast from this new steel have greater load-carrying ability – in fact, in most instances, lighter castings can be used. No bending has occurred, although grouser bars have worn completely away. A large track shoe was reduced from 280 to 190 lb. in weight because the high yield strength of this alloy steel permitted thinner tread and rib sections.

Molding methods adapted from precision casting processes would enable this high-strength steel to be used in aircraft, automotive and industrial applications. Experience in the iron ore ranges has proven its utility for extremely high-strength structural components. The newer molding techniques will produce the desired notch-free surface necessary for critical structures subjected to high stresses.

Are Metallurgists Prepared for 19XX?

*By R. F. THOMSON**

While the foreseeable problems concerning metallic materials appear formidable in the extreme, the metallurgist has never before had so many good tools to attack them, and there appears no reason to anticipate anything but success. (A-general)

WILLIAM PARK WOODSIDE, in the fall of 1913, invited a score of friends – mostly hardening room foremen – to meet at the Fellowcraft Club in Detroit to discuss mutual problems. From this group sprang in succession the "Steel Treaters Club", later the "Steel Treaters Research Club", "Steel Treating Research Society", the latter being one of two groups consolidating in 1920 into the American Society for Steel Treating whose name was changed in 1933 to American Society for Metals. Woodside can therefore be called *the* founder member of A.S.M.

In trying to select a subject for presentation in his honor, I recalled his recent obituary in the Detroit Chapter *News* which said: "His equipment was his forge, his anvil, an assortment of home-made tools, his strong arms and his eyes. No instrument had been invented to tell him the temperature of the steels he forged and hardened. His only association with horsepower was in applying shoes to the real article. He recalled that his main blacksmithing interest was in tools."

Mr. Woodside's interest in tools was not accidental. It leads me to the topic for this discussion: "Are Metallurgists Prepared for 19XX?" To lead into this, I can do no better than to recall that man's progress has always been dependent on his available *tools*, and that the question I am about to examine may be answered with a fair degree of assurance if we know that the tools we now have are sufficiently potent to attack our present day problems.

At the risk of oversimplification, because of

* The 15th annual William Park Woodside Lecture before the Detroit Chapter. Dr. Thomson is head of the metallurgical engineering department, research staff, General Motors Corp., Detroit. He desires to acknowledge assistance of various members of his organization, especially George H. Robinson, for spade work and critical review, and of the various authors not given specific credit in the references.

brevity, it may be stated that our physical tools in this year of 1958 are mostly made of metal. Compared with a century ago, we have a great number of commercial metals available. In 1850, for example, the principal metals were antimony, bismuth, copper, gold, iron, lead, mercury, nickel, platinum, silver, tin and zinc, and the estimated world production was on the order of 10,000,000 tons of iron and 250,000 tons of all the rest put together.

Since 1850 there have been many additions to this list, such as aluminum, magnesium, chromium, titanium, zirconium, molybdenum and tungsten. The stability of the oxides of each of these "new" metals is much greater than the oxides of the "old" metals; the new ones could not be produced in commercial quantities until the metallurgist had tools whereby to concentrate the necessary energy to reduce the ores and melt the metals. That is to say, he required electrical energy and better refractories – new tools. In turn, the mining of large quantities of ores and fuels and their transportation required engines – new tools – and these in turn required cheap and good metals for their construction.

In view of this relationship between progress and tools, we can examine the tools we now have in mid-20th century, and see how well we are equipped to move forward in the next 50 years.

The Tools of Progress

The tools now at our disposal for a frontal attack on the problems which face the metals engineer are being developed at a constantly increasing rate. The list is long and impressive. Certainly they include the following: (*a*) manpower and financial support, (*b*) understanding, (*c*) available materials, (*d*) tools for producing new materials, and (*e*) tools of measurement. Let us consider each, very briefly.

Man Power and Financial Support – In sheer bulk of man power devoted to scientific and engineering work alone, there is a tremendous growth. This is shown by the following estimate of the number of scientists and engineers in the United States:

Year	Scientists and Engineers	Expenditures
1930	261,000	$ 166,000,000
1940	378,000	800,000,000
1950	740,000	2,500,000,000
1956	950,000	6,000,000,000

Not only is there a significant growth curve in bulk of man power, but their training is becoming more intensive and extended, and their access to existing knowledge is larger and easier than at any time in our history. I am not one who is inclined to discount this resource, this "tool", in relation to what is being done in any foreign state, slave or free.

We also find an increasing supply of dollars being spent to explore and develop new frontiers. Much of this money goes into facilities available for future use, so we indeed find a compounding of funds and capital available for new developments.

In our present man power and financial support, we therefore have a powerful tool to attack tomorrow's problems.

Understanding – As more and better prepared man power and more funds have become available, our understanding of physical phenomena is increasing at an accelerating rate.

Historically, it has been generally true that understanding has followed invention. For example, the internal combustion engine was a reality nearly 150 years ago. The mechanism of flame propagation is just beginning to be understood. Again, for example, we do not yet fully understand how to improve corrosion resistance on theoretical grounds, yet many corrosion resisting alloys have been and are being developed by cut-and-try methods.

Probably the most spectacular development where understanding *preceded* invention – a rather rare situation – is the nuclear fission reaction. Laboratory studies in the middle 1930's indicated the possibilities – indeed the conversion of matter into energy had been predicted by Einstein in 1905. Then in the early 1940's the University of Chicago pile was built – designed from the theoretical understanding and prediction.* One cannot resist the temptation to predict the next century will see an increasing number of developments which grow out of an understanding of physical phenomena. This may well be the most outstanding development in this period.

More and more we are coming to understand the nature of the atom, the forces holding atoms together, the nature of particles, binding energy of the nucleus of the atom, and behavior of the surrounding electrons. These are the essentials of such matters as the laws concerning solid solutions, already formulated in part by Hume-Rothery, and the general rules governing metals apt to "weld" or "score" when put in sliding contact with steel for bearing materials. Roach and

*See "The Nuclear Chain Reaction", *Metal Progress*, December 1957, p. 65.

Goodzeit of General Motors Research Staff believe at least one correlating parameter is that metals which have appreciable mutual solid solubility tend to seize or score.

As we continue to spend more and more man hours on understanding, I think we are faced with a real challenge in research administration to decide which is the better course to pursue to maximize the efforts of scientific personnel. What proportion should be spent on "fundamental" research; what proportion on "applied"? Those in administration must be sure we are utilizing the right tools of research for each particular problem. The United States cannot afford to waste its scientfic and engineering man power.

Available materials comprise one of the most important of all the tools now at our disposal. They are available to us in two different senses – one involves *how much* of a material is available to us, and the other *what it can do.*

Insofar as *quantity* is concerned, the people who predict shortages overlook two important factors. One is technological progress which enables us to use ore today which we couldn't (or, more important, didn't have to) use yesterday. The other factor is that what was not economical yesterday becomes so today – for example, the taconites which we will use in increasing quantities as the richer Mesabi ores are exhausted.

An important consideration in this respect is the amount of energy required to produce a unit quantity of metal. In general, we can expect this to increase. For example, C. A. Scarlott, in "Utilization of Solar Energy", reports that "to produce a ton concentrate from taconite rock for the blast furnace requires at least 50 times more energy than easily mined, directly usable Mesabi ore." E. C. Smith, director of research for Republic Steel Corp., adds: "This may be more than recovered in lower energy consumption when processing the rich concentrate in the blast furnace". It requires the following total power to produce one ton of steel ingots:

	Actual Fuel Requirements
Taconite ore at mine	0.5×10^6 Btu.
Pig iron from blast furnace	20.3
Steel ingots from openhearth	3.5
TOTAL	24.3×10^6 Btu.

This leads us to the all-important subject of fuels.

Estimates of fuel reserves are generally pessimistic. Historically, however, new energy sources have become available before they were needed. For example, about the time we started to worry about the dwindling forests in the United States, we began to use fossil fuels, and about the time we began to worry about diminishing fossil fuels, we began to tap nuclear energy, and the extent of this source of energy – to say nothing of solar energy – is probably dependent on man's ingenuity alone.

Consumption of energy in the United States in 1953 has been estimated by C. A. Scarlott as follows:

	Consumption	Reserves
Coal	0.012 Q	7 to 25 Q
Petroleum	0.017	1.4 to 3.4
Natural gas	0.010	0.2 to 0.3
Hydroelectric power	0.0004	
TOTAL	0.0394 Q	8 to 30 Q

where Q equals a billion billion (10^{18}) Btu.

How long can we continue to use energy at this rate? Some estimates of total present fuel reserves are also given above, and in addition there is about 150 Q of heat available from the estimated uranium ores; and a limitless amount from heavy hydrogen, once the fusion reaction is commercialized. We also receive about 30 Q per year as solar energy falling on the surface of the United States.

While it looks as though these resources are adequate, we cannot say that either nuclear or solar energy is now competitive with fossil fuels except in special circumstances. Cost of energy from natural uranium will undoubtedly decrease, while cost of energy from fossil fuels will increase. The efficiency of converting solar energy into useful energy is generally low. According to Scarlott, a "perfect" solar engine (operating between 25 and 65° F.) has a practical efficiency of 16% or less; the announced efficiency of the silicon solar battery is 8%; photosynthesis under the best laboratory conditions yields only 25%, while the conversion for even the best plants, such as sugar beets, is about 2%. If we depend only on solar energy, we would have to capture 1/750th of all the energy falling on the United States and convert it to useful energy at 100% efficiency to meet present requirements. This appears rather improbable.

One can expect, therefore, that as time goes on new fuel sources will be developed. Most or all of our other real and fancied shortages will depend upon how well we can tap new sources of energy.

If you ask yourself what have we ever really run out of in past history, I'm sure you'll find the list quite small. The only instance in history I can find has been loss of a climate in which man

can work – for example, the encroachment of glaciers during the ice age and of desert areas in Sahara, Mesopotamia and our great West. With enough energy, I'm not sure we can't even surmount future obstacles such as these if we have time to prepare for them.

If we turn our attention to the problem of what materials can do for us, we find we are bound by certain physical laws which we probably cannot change. On the other hand, we certainly have not yet achieved the practical limits in many directions. For example, take the tensile strength of iron and its principal alloy we call steel. Wrought iron, the earliest structural material, has tensile strength of about 45,000 psi. The low-carbon bessemer structural steels which have supplanted this ancient material for the last century are considerably stronger (65,000 psi.), but this seems rather modest in comparison with the 200,000 of heat treated alloy steels frequently used in common automotive applications, the 275,000 in alloy steel forgings for aircraft landing gear, and the 400,000 psi. possible in conventional engineering alloy steels. "Whiskers" of pure iron – single crystals almost free of imperfections – test upwards of 2,000,000 psi. One therefore cannot help wondering if many new and stronger materials will be produced by new methods of processing.

We are also much interested in improved high-temperature properties for application in new power plants, rockets, and nuclear reactors. We already have the range of alloys shown in Fig. 1. Much current research is on alloys of the refractory metals, columbium, molybdenum, tungsten, tantalum and chromium, and the ceramic materials and compounds shown in Fig. 2. Little advantage has yet been taken of these materials of high melting point, or mixtures of them which may be even more heat resistant. New methods of processing, especially at high temperature and very high pressure, may be necessary.

These last-mentioned tools have enormous potentialities. For example, we have some new wear resistant materials with rather interesting aspects, such as boron nitride – a material similar to graphite in one crystalline form and to diamond in another. In the hexagonal form, its lubricating properties are exceptionally good and it has been termed "white graphite". High temperature and pressure (3000° F. and 1,000,000 psi.) convert this into a material as hard or harder than diamond. (See "The Borazon Story", by L. Sandek, *Research and Engineering Management*, March 1957.)

An even more intriguing story is one concerning metallic cesium. When the pressure is high enough, the electrons shift out of their normal orbits to new ones with considerable increase in density. S. S. Kistler, in the book, "High Temperature – a Tool for the Future", writes: "A polymorphic transition from body-centered cubic to face-centered at 325,000 psi. pressure had been

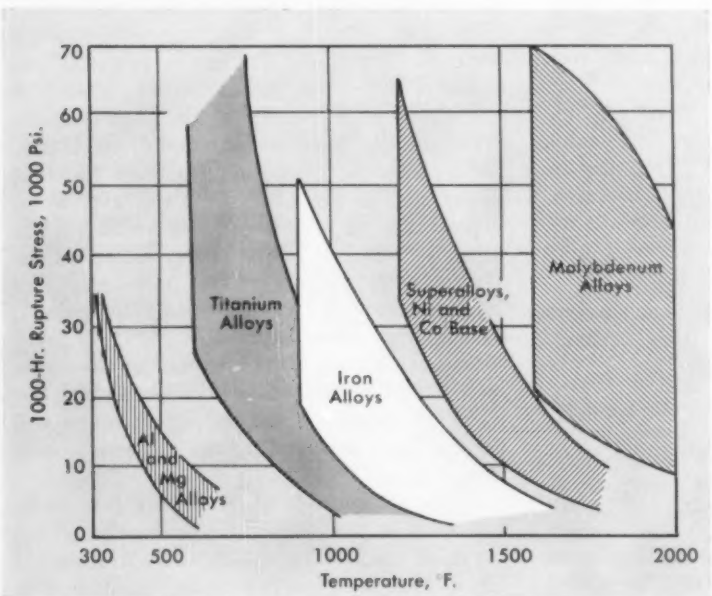


Fig. 1 – Stress-to-Rupture in 1000 Hr. Versus Temperature of Test for Various Metallic Alloys. (Courtesy Climax Molybdenum Co.)

predicted on theoretical grounds. Since the face-centered structure is the densest packing, there should be no denser phase possible, but at about 610,000 psi. another transition does occur involving a 16% decrease in volume – due to the electron shift mentioned above. The same kind of shift occurs in the rare earths – for example, cerium shows a 16% decrease in volume, accompanied by electron shift, at about 170,000 psi. pressure."

It is not too much to expect that the unfavorable structure of ceramics may be changed for the better, to correct that perplexing problem of brittleness which so far has limited their usefulness. While it has been known for years that under certain conditions single crystals of silver chloride and sodium chloride can be bent, it has only recently been announced (in *Aviation Age*, June 3, 1957) that ductile magnesium oxide crystals about 0.5 in. long have been bent 15°.

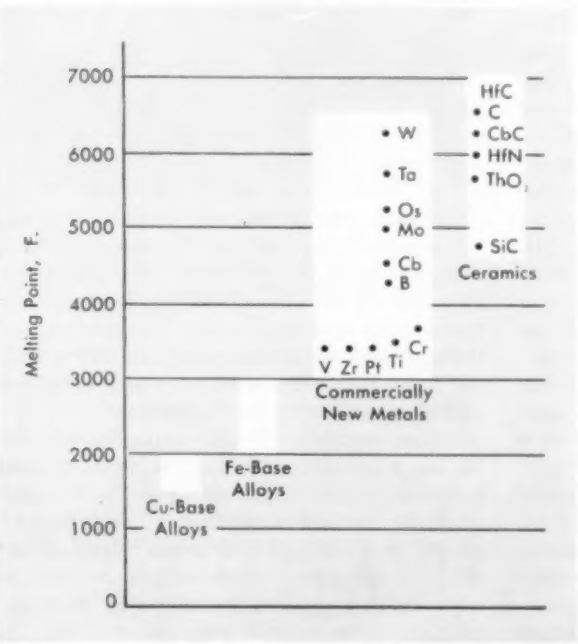
In summary, I believe we will find ways to obtain the necessary new materials if the energy is available to wrest them from nature. New materials appear on the horizon, made by some newer techniques which open whole new vistas of opportunity. The picture is encouraging.

Tools for Producing New Materials – To produce new materials we will need some new tools. We might well note that we now have some processing tools which offer new horizons of development – first, fuels and second, mechanical tools.

In the field of fuels, we can produce higher temperatures and more concentrated energy than ever before. The oxy-acetylene flame has long been cited as the maximum intensity obtainable commercially (about 5700° F.), but A. V. Grosse recently reported considerable increases now available: oxy-aluminum, 6400° F.; oxy-zirconium, 6700° F.; hydrogen-fluorine, 7500° F.; cyanogen-oxygen at 1 atm., 7900° F., and carbon subnitride, 9450° F. The nuclear fission and fusion reactions produce temperatures measured in millions of degrees.

The reason for interest in high temperatures is very clear. It enables us to do things which may be difficult to do otherwise. For instance, the stabilities of metallic oxides generally decrease as the temperatures go up, so that if sufficiently high temperatures can be attained, it is theoretically possible to reduce the oxide even in the absence of reducing agents. Furthermore, the reverse is true for the oxide of carbon. Theoretically, alumina is reducible by carbon above 3500° F. We also have an ever increasing list of mechanical tools which enable us to process in some new ways. For example, new furnaces: The induction furnace with the use of suitable susceptors can reach 6500° F. They operate with or without pressure and in nearly any atmosphere we choose. In them we can test materials for rockets and jet engines; form carbides, cermets and ceramics; and cause chemical reactions such as reduce MgO with carbon. Under good conditions at the earth's surface, J. Farber believes that a temperature of 4000° K. (6740° F.) can probably be obtained in solar furnaces. Limitations of resistance furnaces are primarily the melting point of the resistor. Thorium oxide (5970° F.) and tantalum carbide (7000° F.) are possibilities for high-melting resistors.

Fig. 2 – Melting Points of Metals and Ceramics



A novel method of heating by electron bombardment in vacuum utilizes the circumstance that X-ray tube anodes are heated by bombardment with low electron currents moving at high velocities. A setup for floating zone melting is shown in Fig. 3 wherein tungsten and rhenium have been melted and recrystallized.

In summary, we now have at our dis-

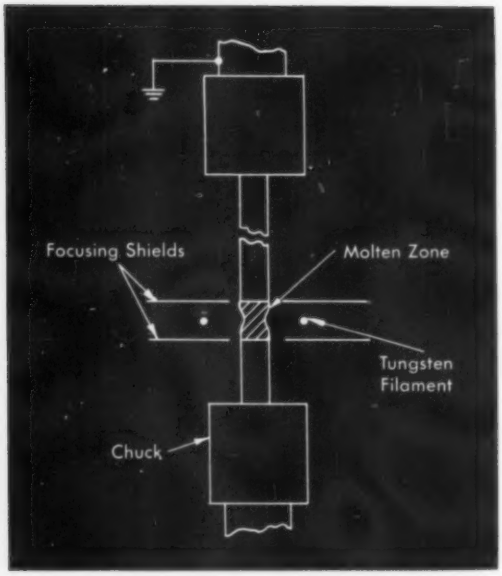


Fig. 3 – Equipment Used by Davis and Co-Workers for Floating Zone Melting by Electron Bombardment

posal furnaces which produce continuous temperatures as shown in Table I.

In the field of processing equipment, the past 25 years has seen tremendous development, and these powerful extrusion and forging presses of 50,000-ton capacity can be used to fabricate the stiff and strong metals and metal-ceramic combinations. Molybdenum generally has been fabricated on steel mill equipment. This means that, in effect, these refractory metals have not been hot worked – that is to say, they have been worked below the recrystallization temperature. Recently news comes from Germany that molybdenum has been rolled at 3000° F. and this has resulted in metal with a hot worked structure.

This combination of high temperature and pressure will certainly permit the development of new alloys.

Improved tools of measurement are another potent means for making future progress in the field of metallic materials. Space is sufficient only for listing some interesting ones: (*a*) Improved analytical tools to determine trace elements or small intentional additions – a few parts per hundred million; (*b*) electron probe micro-analyzer to explore variations in composition within a single crystal; (*c*) the mass spectrograph to control vacuum melting by analyzing the gases evolved during the heat; (*d*) the field ion microscope with resolving power of 3 Angstrom units. The best resolution of electron microscopes is 5 to 10 A, which is about the spacing between crystallographic planes of large and complex molecules, whereas Fig. 4 shows the atomic configuration in a tungsten crystal.

In summary, we have more and better tools than were ever available before and they are going to enable us to see things which we have only conjectured about in the past, and they are sure to bring to us some new concepts as we better understand specific conditions and phenomena.

Present and Future Problems

Now let us turn our attention to some of the problems of 19XX.

It would indeed be presumptuous to try to predict all the problems we will face in the last half of this century but we can compile a partial list of those we face in 1958 and see how well prepared we are with suitable tools for solving them. These problems include (*a*) high temperature, (*b*) unification and correlation of existing and new knowledge, (*c*) space travel, (*d*) supply of materials and energy, (*e*) improved life of components, (*f*) nuclear containment, (*g*) materials of high purity and controlled structure.

Table I – High-Temperature Furnaces

Type	Maximum Temperature	
	Oxidizing	Inert
Resistance	3,600° F.	7,000° F.
Induction	3,300	6,500
Arc	3,300	14,000
Solar	5,400	—
Electron bombardment	—	> 6,000
Nuclear	>10,000	>10,000

High-temperature problems will include the development of power plants requiring new materials which will, first, contain the high temperatures; second, resist wear, stress and corrosion in hot atmospheres; and third, require melting and processing at temperatures above 3000° F.

In the containment of the high temperatures, we are approaching the melting points of most known materials. The most promising approach appears to be containment in a magnetic field which keeps the high heat source out of contact with the container. Metallurgists are already applying this general technique in levitation melting, where a small mass of metal may be

melted in an inductive field while it is supported only by the interaction of two opposing magnetic fields. The high-temperature source itself may be similarly contained.

Materials with improved wear, strength and corrosion properties are already foreshadowed by new types of materials, such as hard boron nitride and dense cerium produced at very high temperatures and pressures. The application of such techniques to ceramic materials has hardly begun.

Finally, the fact that these new materials may require processing above 3000° F. does not appear unduly troublesome because furnaces utilizing newer fuels and energy sources are already available, such as susceptor induction furnaces. While these new materials may be very strong and difficult to process, the fabrication problems may be met by the tremendous 50,000-ton presses already referred to.

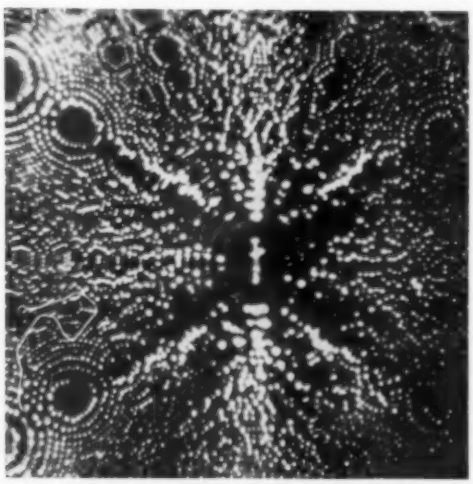


Fig. 4 – Field Ion Microscopic Pattern From Tungsten Crystal, Showing the Atomic Configuration. Magnification about 10^6 times. (E. E. Müller in Scientific American)

Unification and correlation of existing and new knowledge is one of the real problems facing anyone in the technical and scientific field today. How can he keep abreast of the voluminous literature and data now available? It is physically impossible for any one individual to read the pertinent literature if his interests are at all broad.

Some idea of the mass of available metallurgical literature can be obtained from the 1955 Review of Metal Literature where some 7500 indexable articles were catalogued from 360 English and 157 foreign periodicals. If one assumes an arbitrary figure of ten issues per year for each of the periodicals, this means that there are 5350 individual periodicals per year available for digestion. One might guess there are at least five original articles per issue which means a minimum of 15,000 articles per year in metallurgical periodicals alone!

Even if reading were practicable, remembering what and where the data are is impossible. Fortunately, "memory" machines are now fairly well developed where information is encoded on magnetic tape, punched cards, or photographic film and can later be retrieved on demand. The American Society for Metals is now halfway through a five-year program of this sort and there is every reason to expect a successful outcome, there already being in operation a prototype machine which is able to retrieve correlated information as well as direct answers to a main inquiry. It is probable that one could ask such a machine for a literature search on a specific subject and obtain the available information in a matter of minutes. An additional feature would be the ability to sort information as it is currently fed into the machine – keeping current in a given field is frequently more important than finding out what was done ten years before. These "brain" machines will possibly supply the information in any language we desire, even though they may have absorbed it initially in several different languages.

These electronic brains may solve another most perplexing problem. One of the difficulties facing those of us in the development of new materials is that we have no way of correlating phase information on systems with four or more components. For example, a binary composition diagram enables us to select compositions which may be hardenable, and to decide what the limiting compositions are which will harden. A ternary system can be represented in a trigonal pyramid. But when one gets to four or more components, we cannot make a phase model do a similar job for us because space is ordinarily three dimensional. Electronic machinery, however, can handle four, twelve or twenty dimensions as well as three, so we may expect some day that equilibrium diagrams of multicomponent systems will be stored on tape and we can ask questions about the metallurgical characteristics of specific alloys.

Space Travel –This intriguing possibility is on everybody's mind, now that Sputnik I and II and the "Explorer" have sucessfully remained

aloft. The prospect of travel in inner and outer space presents a whole host of new problems, such as (*a*) aerodynamic heating of structures to temperatures where aluminum will melt, and (*b*) guidance systems which will send a nonmanned vehicle 5000 miles away from its base and deliver it exactly on target.

The aerodynamic problem will always present an ever-moving target to the metallurgist, but new high-temperature materials, improved design and better known stress states will be the tools applied to this problem.

In the field of guidance systems, where dimensional changes on the order of a millionth of an inch over a period of a year will be enough to cause the vehicle to drift off target, we have new measuring devices of this range of sensitivity, and there has already been appreciable progress in developing structural materials with unheard-of stability. This problem will receive much attention in the coming years.

Supply Problems – We have already tapped new sources for materials, such as magnesium from sea water and iron from low-grade rock. Aluminum from clay and zirconium from beach sand are new sources of supply. New energy from deuterium in sea water has already been mentioned.

Improved life of components presents many problems today. For example, take wear resistance. One of its most important aspects is the wear of the cutting tool or forming and forging dies. With increasing use of automation with its accompanying large capital investment, it becomes increasingly important to lengthen the periods during which machinery will operate before shutting down for tool changes. New ceramic cutting tools and cast, wear resistant, forming tools have already made some gains in this direction. In the General Motors organization, we have already utilized precision cast, wear resistant materials for some tools to replace the wrought materials. In the latter, a compromise between wear resistance, workability and machinability had to be made; no such compromise is necessary in the precision cast, wear resistant tools.

In the field of corrosion, "new" metals like titanium and zirconium can largely decrease the rate of corrosion in certain severe surroundings. The great amount of research on the mechanism of corrosion and surface chemistry reactions should shortly lead to a better understanding of the fundamentals.

Early and unpredicted fatigue failures in components such as bearings is a formidable problem, especially in high-performance machines. Powerful tools now being applied to this problem include intensive work to produce inclusion-free and hydrogen-free raw materials and finished parts, and the use of X-ray diffraction to control residual stresses in hard materials.

Nuclear Reactors – Containment of radioactive fission products in nuclear reactors, the stability of materials under intense neutron bombardment, cheap reprocessing of partially spent fuel elements, high permissible burnup of fissionable materials, and more efficient conversion of nuclear energy to industrial use – all these problems are being faced by a vast amount of man power and research expenditure.

Materials of High Purity – Production of cheap and uniform materials of transistor type is a challenging problem. Special melting and solidification techniques, and analytical tools such as radioactive tracers to control minute additions, promise solutions to these problems.

There is a real possibility that the superconductivity noted in some materials near absolute zero may be extended into more usable temperature ranges. For example, one can easily imagine that if the electrical conductivity of aluminum could be raised to 150% of its present value, vast new frontiers would be opened in the electrical industry.

Summary

In summary, this brief analysis of tools available to us in 1958 and some of the problems now facing us leads to the conclusion that the problems facing us are more difficult, more costly and more involved than ever before. But, at the same time, the metallurgist has never before had so many good tools available to attack these problems. We have more man power, financial support, understanding, readily available material, new tools for producing materials and for measuring their characteristics than ever before.

I am supremely confident that we are making fantastic strides to meet the metallurgical responsibilities of the last half of the 20th century. So while one can never be too well prepared, I am sure there is no "Dark Ages Era" just around the corner in metallurgical progress. The metallurgist is doing his part to make the last half of this century as startling and awe inspiring as was the first half, when William Park Woodside, Founder Member of the American Society for Metals, whom we delight to honor, spent the most fruitful years of his life.

Controlled Thermonuclear Reactions

A PAGE under this title in *Metal Progress* for September 1957 contained quotations from the 22nd semiannual report of the U.S. Atomic Energy Commission which described briefly how the heavy isotopes of hydrogen H^2 and H^3 can fuse together. The result is helium (He^3 and He^4) which weighs slightly less than the components, and the reaction produces neutrons and the correspondingly large amount of heat according to Einstein's equation relating energy and mass, $E=mc^2$.

On Jan. 24 some documents were released simultaneously in London and Washington which indicate that since 1956 the research programs of the Atomic Energy Authority (Great Britain) and the Atomic Energy Commission (United States) in this field have been closely cooperating, exchanging information and conclusions. A recent revision of the Joint Classification Guide—binding on Great Britain, Canada and the United States—permits publication of most of the information gathered to date in this area.

In the United Kingdom the research workers have succeeded in producing temperatures of 5,000,000° C. in a hydrogen "plasma" (deuterium ions and electrons) for periods up to 0.005 sec., repeated every 10 sec. Up to 3,000,000 neutrons are emitted from the gas during each pulse; being non-magnetic they escape from the apparatus and can be counted. The actual temperatures and times are far below those required for the thermonuclear reaction—properly defined as a *continuing* conversion of heavy hydrogen into helium—so it is uncertain whether the neutrons were knocked off H^2 or H^3 ions by collision or whether the *occasional* generation of some helium (true fusion) occurred during these pulses of power. However, in the British "Zeta" apparatus "the number of neutrons produced by each pulse of energy was what might be expected from a thermonuclear reaction at the measured temperatures, and it will be very surprising if they are not thermonuclear neutrons". The British scientists believe there is no fundamental reason why the higher temperatures and longer times for useful power generation cannot be achieved.

Experiments with the Zero Energy Thermonuclear Assembly Zeta started at Harwell, England, in August 1957. It sets up an electric charge in a round tube of deuterium gas H^2. The action is analogous to that of a neon sign. This electric discharge heats the gas and also produces an intense magnetic field around the gas column, which constricts the column, increases the electrical density, and heats the gas still more. To suppress the wriggling in the gas column which might then touch the container tube, an auxiliary magnetic field is applied parallel to its axis. The tube is a torous or doughnut of 1-m. bore and 3-m. ring diameter. Encircling part of the tube is the iron core of a large pulse transformer, connected to a bank of capacitors capable of storing 500,000 joules of energy. The equipment can generate 200,000 amp. of direct current in the ionized gas for periods up to 5 millisec. and this is repeated at 10-sec. intervals.

In the United States, three different pieces of apparatus have been employed. One—given the fanciful name of "Perhapsatron S-3"—is a small edition of the Zeta. The others are straight tubes called "Columbus II" and "Columbus S-4" for studying the so-called pinch effect. "Columbus S-4", the larger equipment, is essentially a 5-in. porcelain cylinder, 2 ft. long. Temperatures of about 3,000,000° C. are attained in it, when operating at 20 kv. and gas pressure of 40 microns. For orientation, 5,000,000° C. is higher than the surface temperature of any star which has been measured; 25,000,000° C. is the computed temperature at the center of our sun, where a gas ("plasma" is more correct) composed of H^2 and H^3 in equal parts fuses into helium at a steady rate, producing just about enough nuclear energy to make up for its radiation losses.

The pinch effect noted above results from the magnetic forces set up by the current—which in turn is the passage of negatively charged particles or electrons toward the positive terminal and the passage of positively charged particles or ions toward the negative terminal—tending to force both the electrons and ions toward the center line of the current. Thus the discharge automatically pinches itself down to a smaller diameter. Hence, exceedingly high temperatures—or, what is the same thing, correspondingly high velocities of the moving ions—are achieved without contact with the container. Unfortunately, the pinch effect is rather unstable, and much study is now being given by physicists in many countries to auxiliary magnetic fields whereby the hot discharge is kept from wandering off and touching the walls.

In commenting on the above facts contained in the official British and American releases, the scientific correspondent of the *Manchester Guardian Weekly* states that the energy released in a single pulse in Zeta is only a small fraction of that required to produce the electrical charge, so Zeta is not a power producer. However, it is the first machine in which any power of thermonuclear origin has been produced. The way is now open to build a machine which should make more power than it consumes, and thus provide the crucial information for the design of commercial power stations. While these, in all probability, will be conventional in the sense that the heat will generate steam to drive a turbine coupled to an electrical generator, there is the chance that a considerable amount of electrical power may be drained off directly, by methods and equipment yet to be discovered. Barring some "break-through" in physics, metallurgy, or materials engineering, these goals—even the most modest—may not be expected for at least 20 years.

Heat Treating in Vacuum

*By HORACE B. DREVER**

Vacuum melting is a familiar process; vacuum heat treating is relatively new. Annealing, tempering and hardening are possible, though some precautions must be observed. A few examples are described. (J2, 1-73)

WHILE METALS have been melted and cast in vacuum for several years, the product resulting – from casting to finished part – has usually been processed in some natural or manufactured atmosphere. However, the highly reactive metals such as titanium and tantalum have required heat treatment in an evacuated chamber to avoid surface contamination. The development of vacuum heat treating methods for these metals naturally led to attempts at processing the more conventional materials. For several years, the heat treat division of Drever Co. has operated vacuum equipment in which a variety of metals, including such prosaic types as mild steel and Armco iron, have been treated. This work has shown that heat treating, properly used, can produce a better product than the usual methods can. Faster rates at lower costs are also indicated.

Vacuum heat treating furnaces generally are one of three types. The simplest is merely an evacuated chamber heated by gas, oil or electricity. This is used chiefly for annealing.

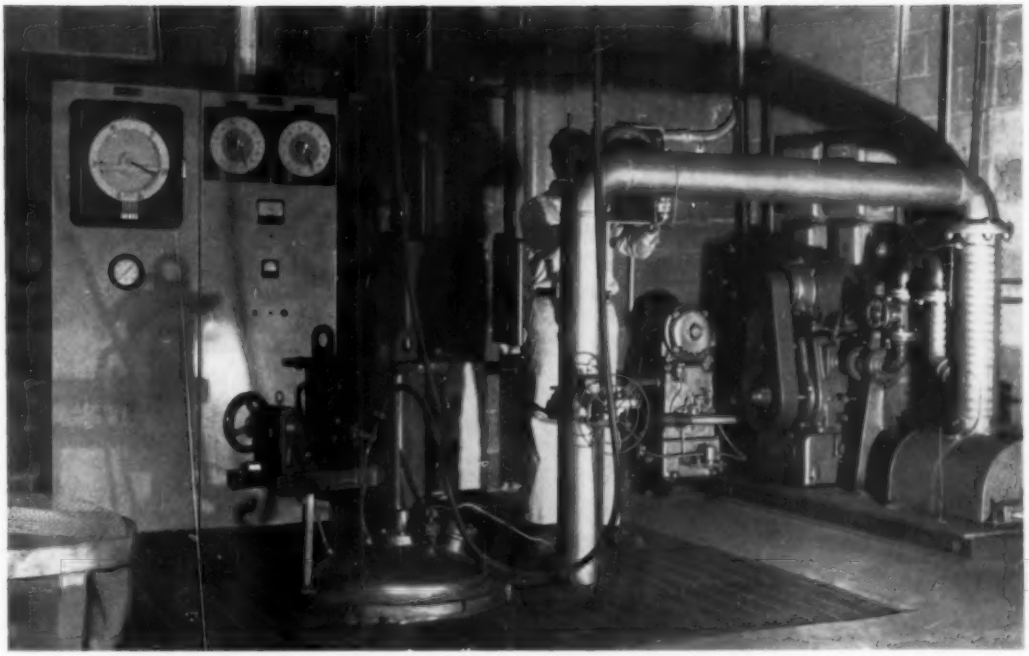
For larger retorts and higher temperatures, the heating zone is also evacuated. Such a furnace is illustrated; instrumentation, pumps and hoisting mechanism are also shown. It rests in a pit, with the top of the retort at floor level. This ¼-in. Inconel retort is 21 in. diameter and 24 in. deep; 2150° F. can be reached.

The third type (a variation of the second) consists of an evacuated retort surrounded by reflective insulation which contains the heating elements. This installation – and the evacuated furnace – can only be heated by electricity.

*Metallurgical Engineer, Drever Co., Bethayres, Pa.

Furnaces of all three general types can be arranged horizontally or vertically; they can be bell-type or drop-away furnaces and may or may not have cooling sections. The vacuum pumps are dependable and rugged machines, easy to maintain and easy to operate. For these furnaces, the rough vacuum is produced by a rotary piston pump while the high vacuum is achieved with a booster pump of the oil vapor or mechanical type. For most heat treating operations, a vacuum of 0.1 micron is satisfactory. The tightness of the retort and manifolding are obviously of importance. The pumping system and retort are thoroughly tested before operation by a mass spectrometer to pick up indications of in-leaking helium, the helium being applied at all welds and joints. Pressure rise in the system because of leaks can be held to zero providing that test procedures are followed carefully.

Metals can be annealed, tempered and hardened in a vacuum. One example is the bright annealing of mild steel and Armco iron parts. Conventionally, these would be loaded into an alloy retort which is then sealed and purged with the protective atmosphere. Heating for the required cycle follows; on cooling, the stock must be protected by expensive atmosphere gas until it is below oxidation temperature. It generally takes 28 to 30 hr. to complete a typical anneal. The gas (and thus its cost) is eliminated by vacuum equipment and the total heat takes but 24 to 26 hr. With Armco iron used for electrical purposes, a better product is produced because the metal is degassed during the annealing operation.



A Vacuum Heat Treating Furnace with Heating Coils in an Evacuated Chamber. The furnace is below floor level; instrumentation and equipment are shown

Vacuum heat treating is also useful in the bright tempering of stainless steels. Many of them require bright hardening and tempering in a 1000 to 1050° F. range. Maintaining bright work in an atmosphere at this tempering range is extremely difficult; a blush or a tan discoloration frequently results. Further, the temperature is most critical; as little as ± 10° F. results in a hardness outside the required limits. If the stainless steel is tempered in a vacuum below 0.5 micron (with a retort having a low leak rate), the work comes out as bright as it went in. An almost exact temperature can be maintained by a control system governed by a thermocouple placed directly on the work; of course the connection to a potentiometer is through a vacuum-tight fitting.

Perhaps the most unusual use of a vacuum furnace is for hardening. Since the only heat exchange in a vacuum is by radiation, it is logical to assume that cooling would be too slow to obtain high hardness.

However, if the furnace has a water cooled section to the retort and a means for moving the work to this cooling section, some stainless steels and toolsteels can be hardened. Though expensive, it may be desired to keep finished surfaces intact.

Three examples follow:

1. An air hardening toolsteel, heated to 1850° F. and soaked 1 hr., comes out of vacuum with a C-62 Rockwell reading.

2. A hardenable stainless steel of the 440 C analysis, 1 in. thick, treated at 1875° F. for 1 hr. hardened to a Rockwell C-58 to 60.

3. A 420 stainless steel die, 2 × 10 × 12 in., treated at 1875° F. for 1 hr. and cooled has a hardness of Rockwell C-50. Such a die with highly polished surfaces would be slightly etched if it were quenched out of a salt bath.

Nonferrous metals can also be heat treated in a vacuum, although there are some unusual problems involved. Copper is very successfully annealed in a vacuum – especially the oxygen-bearing grade. Brass, however, loses zinc when heat treated in a vacuum. Zinc, tin and magnesium are three of the more common metals with high vapor pressures at heat treating temperatures; they sublime in the vacuum furnace and form a vapor.

While not the only answer to a heat treater's problems, the future of vacuum heat treatment seems assured. With further development, the process may very well prove to be the answer in cases where the maintenance of a good surface is the prime desire.

Book Review...

Carburizing

Reviewed by E. E. THUM

REAUMUR'S MEMOIRS ON STEEL AND IRON, a translation from the original printed in 1772, by Anneliese Grünhaldt Sisco, with an introduction and notes by Cyril Stanley Smith. University of Chicago Press. 1956. 396 p. plus 17 full-page plates $6.00.

IN the early 1700's, all the so-called fine steels made into cutting tools were converted from wrought iron bars by secret processes. Foreign importers busily emphasized that the French irons were of no use as raw material. Réaumur, however, had observed that excellent files were being made in France by what we would now call case hardening or pack carburizing. He then searched for the proper methods to turn the iron bar into steel to its very center.

Réaumur was not what we would call a metallurgist. He was the son of a wealthy provincial family, so well educated that at the age of 25 he was selected as one of the 70 members of the Royal Academy of Sciences, and his ability and energy soon put him into the post of director. "He was first and foremost an academician at a time when the term implied an interest in whatever was novel and provocative." In his lifetime he contributed 75 memoirs to the Academy on various aspects of physical and biological sciences, only four of which pertain to metals.

It so happened that in 1675, eight years before Réaumur was born, the French Finance Minister requested the Academy to prepare detailed accounts of the various mechanic arts of the realm. Thirty years later the first manuscript (on printing) was ready. Shortly after Réaumur was elected to the Academy, he became editor of these lagging "*Descriptions*," and his attention went to metallurgy from about 1716 to 1726 (possibly because no one else had an interest in it). His original aim was to devise a method for producing castings of equal quality to wrought iron, a matter wherein he thought the superior artistic abilities and the craftsmanship of the Frenchman could well be displayed. Soon his attention was turned to the conversion of wrought iron to steel (a subject somewhat out-of-bounds to the "*Descriptions*" since steel was a commodity not then made in France). His success gave him ideas which led to a method for making white heart malleable – thus coming full circle.

His experiments, described in great detail in this book, were models of the scientific method wherein the surrounding factors were changed one at a time and the effects noted. It is difficult for the mind today to reconstruct the background of "knowledge" on which he worked. For example, "iron" was a metallic substance produced from a natural mineral or ore by a certain process; it had characteristic forgeability, weldability and fracture appearance and could be readily filed. It was not known that iron was a chemical element; the chemists had not yet got the best of the alchemists. Steel was generally considered to be a purified iron. Réaumur weighed some bars before and after cementation and found that the original iron (now steel) was heavier; evidently the iron had gained something rather than lost anything. But what?

In those days, heat ("phlogiston") was regarded as a ponderable substance. Could the addition to iron, converting it to steel, be phlogiston? A series of experiments was made wherein 4-oz. pieces of wrought iron were packed in clay, ashes or lime in small covered clay boxes and heated variously. The iron always remained iron – that is, it remained forgeable, weldable, easily filed and of fibrous fracture. Evidently, phlogiston was not permanently added to the iron.

Similar experiments eliminated such things as borax, alkali, alum, vitriol – "only charcoal soot and burned leather can change the iron

into fine hard steels." Réaumur recognized that certain additions speeded the process, and finally came up with the formula 16 lb. soot, 8 lb. charcoal, 8 lb. ashes of green wood, 5 lb. sea salt – all well crushed and mixed together. "Even the salt could be eliminated but the process would take longer."

What, then, was happening? Cyril Smith, in commentary, says: "Seventeenth century philosophy is shot through with concepts [about constitution of matter] of 'parts' which attract each other, which have spaces between them into which both particles of heat and other matter can diffuse, and by variation of whose packing and natural contact all the properties of hardness, strength and ductility can be quantitatively explained." Accordingly, Réaumur suggested that when iron is converted into steel (or cast iron) "sulphurs and salts" were added, materials fine enough to penetrate into the "parts" of iron when urged by heat. He thought that the "sulphur" was some material particle rather than an alchemical "principle" which, when associated with an earthy matter, ash (?), would form charcoal. He also associated "salt" with "sulphur" because he found that various salts speeded the process.

These quaint expressions should not obscure the prime importance of this early investigation, which rigorously and scientifically investigated an important commercial process, junked all the hocus-pocus with which ignorance and tradition had surrounded it, and discovered the fundamental principles with which variations in the commercial process could be kept under control.

This fascinating book does what all good books do, namely, urges the reader on to other works. This reviewer would suggest Giolitti's "Cementation of Iron and Steel" (McGraw-Hill, 1915) as supplementary reading. In his early chapters, Giolitti outlines the growth of chemical knowledge from Réaumur's through the next two centuries. It appears that Réaumur's work on steel was used to much better advantage by the English than by his own countrymen. Sheffield became predominant in converting excellent Swedish iron into blister steel using nothing but powdered wood charcoal as a carburizer, and later melting it into crucible cast steel. About 1760 (40 years after Réaumur's Memoirs), Bergman, the Swede, showed that graphite – thought to be a compound of phlogiston – changes iron into steel or cast iron. The next step (1780) was taken by another Swedish chemist, Scheele, who identified the graphite in cast iron with "mineral carbon" made of "fixed air", what we would now call CO_2 and "phlogiston". Only a few years later, Lavoisier exploded the age-old phlogiston theory, and it was soon shown by his French compatriots that the "sulphur and volatile salts" of Réaumur were only carbon gradually absorbed into iron.

Interest in cemented steel fell off sharply in the midnineteenth century, what with the invention of the bessemer and openhearth processes. Case hardening, the industrial process of today, also awaited the mass production of machinery in the 20th century. Giolitti points out that little information of a fundamental nature was acquired during this interim, probably because of the puzzling effect of nitrogenous compounds – especially cyanides – on the case hardening process.

By 1900, then, the common view of metallurgists was that solid carbon in contact with hot iron (austenite) diffused inward from its surface. They conveniently forgot that there is a pronounced shadow effect – that areas not in close contact with fine carbon did not harden. By experiments as rigorous as Réaumur's, Giolitti proved that the *direct* action of carbon is so small as to be negligible in commercial case hardening, that the gas, carbon monoxide, is the vehicle carrying carbon from the cement to the surface of the steel, and that what we now call carbon potential of the atmosphere is primarily determined by the mixture of CO and CO_2 in equilibrium at the metal's surface. These ideas are fundamental to all our present-day methods of heat treatment in controlled atmospheres.

Another interesting parallel between these two scientists, separated in time by nearly two centuries: Both believed what they saw. Their eyes were used as instruments. Réaumur's prime method of distinguishing between iron and steel and the quality of each was by the appearance of the fracture – the macrostructure. Giolitti leaned equally heavily on the appearance of a polished and etched cross section – the microstructure. The keenness of his eyes were merely magnified a hundred-fold.

The present reviewer can recommend reading of Réaumur and Giolitti for another reason, and that is that it would immediately distinguish between a good translation and a mere transliteration. The linguistic ability and scholarship of Mrs. Sisco and Dr. Smith shine forth on every page. Typographically, also, the Réaumur translation is outstandingly good. Get yourself a copy and treat yourself to a treat!

Correspondence . . .

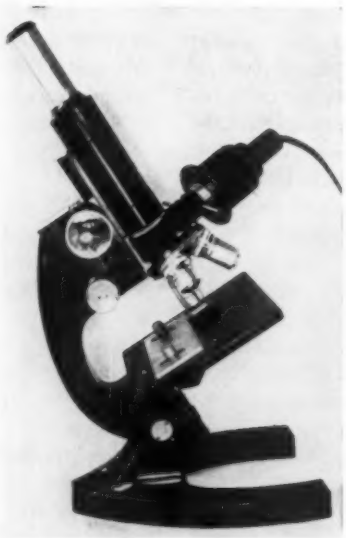
Microscopes to Fit Students

NEW HAVEN, CONN.

Microscope tables are always too high or too low, relative to the length of the observer, the latter usually variable over a wide range. Tilting the microscope is a complete solution, but the usual mechanical stage necessary to keep the specimen from sliding off, at $50 to $75 multiplied by a number of microscopes, produces another unfavorable ratio of cost to budget.

We have found a simple, adequate and inexpensive solution at Hammond Metallurgical Laboratory of Yale University.

Drill and tap two holes in the stage (or tap the two holes already there for spring clips) and attach by two thumb screws a rectangular, slotted plate, 3½ × 1½ × 3/32 in. The slots should be long enough to take care of the width of the usual specimen mount. While it is necessary to move the plate for a complete survey of the specimen, much can be done without moving the plate by simply observing along the line defined by the position of the plate.



Slotted Plate and Thumb Screws Hold Specimen on Sharply Tilted Stage

RAYMOND C. BOETTNER
Assistant in Research
Yale University

Metallurgical Dragon

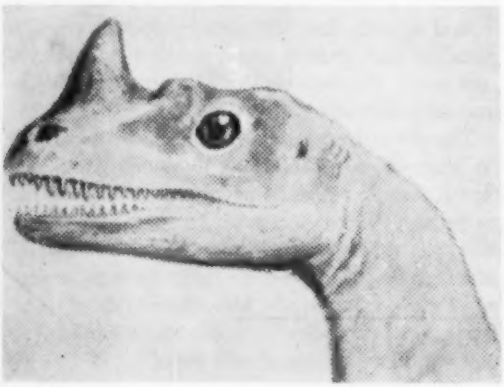
WHITING, IND.

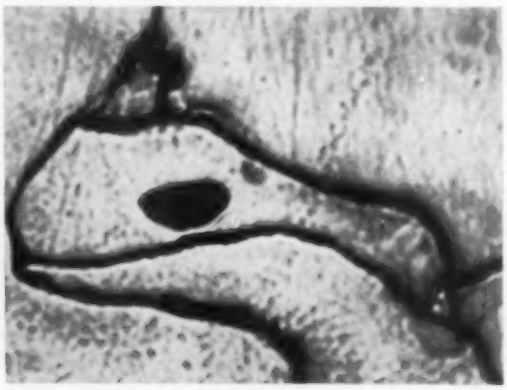
Modern metallurgy has revived what appears to be a monster from a bygone era. In a photomicrograph of sintered Type 316 stainless steel micrometallic grains was found a creature known to exist in the middle Jurassic period of the Mesozoic era, some 140 million years ago. The similarity of the photomicrograph (taken at 250× and magnified 3× in reproduction), and the carnivorous horned dinosaur, ceratosaurus nasicornis*, is remarkable indeed. In metallurgical parlance, this morphology may be termed "cornisaurite".

The petroleum industry, using stainless steels in processing units, such as the filter material shown here, has encountered many problems of a peculiar nature. Could it be that this denizen from the past is to blame?

R.R. BANERJEE
Leader, Metals Research Group
Standard Oil Co.

*Reproduced from Hutchinson's "Extinct Monsters," Chapman & Hall, 1910.





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LEADERS IN SALT BATH DEVELOPMENT SINCE 1936

Personal Mention

David F. Ritchie

Carl R. Weymueller

DAVID F. RITCHIE, assistant editor of *Metal Progress*, has been on the editorial staff of the American Society for Metals for a year and a half. A native of St. John, New Brunswick, Dave graduated from the University of New Brunswick and came to the United States in 1949 to settle in Cleveland. He worked for Euclid Road Machinery Co. and as a welding engineer for Lincoln Electric Co., continuing his education at Western Reserve University and Fenn College where he studied business administration and engineering. In 1955 he began his editorial career as associate editor of the Industrial Publishing Group and a member of the staffs of *Industry and Welding* and *Welding Illustrated*. In August 1956 he joined the editorial staff of *Metal Progress*.

I. S. Levinson has been named sales manager of technical products for Ampco Metals, Inc., Milwaukee, Wis. Until receiving this assignment, he was product manager in charge of process industries sales.

G. G. Hatch has been appointed president of W. S. Atkins & Associates Ltd., Toronto and Montreal, associated with W. S. Atkins & Partners of London, England. A graduate of McGill University and Massachusetts Institute of Technology, he was until recently plant superintendent of the Quebec Iron and Titanium Corp., Sorel, P.Q.

The second assistant editor on *Metal Progress* is CARL R. WEYMUELLER, who joined the staff in November 1957. Born and raised in Chicago, he entered the Army soon after his graduation from high school there and served in the Signal Corps for 3½ years. Discharged from the Army in 1945, Carl spent the next four years concentrating on his metallurgical education and in 1949 received his bachelor's degree in metallurgy from the University of Illinois. Joining Republic Steel Corp., in Chicago, he worked as a metallurgist until July 1957 and, after several months with Wyckoff Steel Co., became assistant editor on *Metal Progress*.

A. L. Leo-Wolf has been named assistant general manager in charge of operation of the newly organized refractories division of the Carborundum Co., Niagara Falls, N.Y. The company's Stupakoff Div., Latrobe, Pa., Globar Div., Niagara Falls, and Refractories Div., Perth Amboy, N.J., have been integrated into one division, now called the refractories division. Mr. Leo-Wolf was formerly general manager of the Globar Div.

Andrew F. Kravic, former instructor in metallurgical engineering at the Polytechnic Institute of Brooklyn, is now associated with the nickel sales department of the International Nickel Co., New York.

Charles E. Nelson, technical director of the magnesium division of Dow Chemical Co., Midland, Mich., was nominated as vice-president of the American Foundrymen's Society for 1958-59. At the same time, **Jake Dee**, president of Dee Brass Foundry, Houston, Tex., was selected as a director to serve for a three-year term.

Norman P. Pinto is now plant manager of the fabrication plant of the Beryllium Corp., Hazleton, Pa. Before accepting his new position, he was head of the manufacturing section of Sylvania-Corning Nuclear Corp., Hicksville, N.Y.

George B. Goodwin has been appointed district sales manager of the new Los Angeles district sales office of Universal-Cyclops Steel Corp., Bridgeville, Pa.

W. A. Keck, formerly district representative in Houston, Tex., for the Sheffield Div., Armco Steel Corp., has been transferred to Tulsa, Okla. Mr. Keck joined Sheffield in Kansas City in 1955 as a sales trainee, and later acted as district representative in Wichita, Kan.

John M. Keyes has been promoted to division technical manager of the recently created new products division of Wolverine Tube Div., Calumet & Helca Consolidated Copper Co., Detroit.

Howard P. Berger has been transferred from Detroit to Cleveland as branch manager of the Wheelco Instrument Div. of Barber-Colman Co.

Daniel A. Sherick has been promoted to plant products manager and superintendent of the Griswold, Ohio, plant of Brainard Steel Div., Sharon Steel Corp. He joined Brainard in 1955 as plant manager at Griswold directing the manufacturing of tubing and remained in this capacity until his recent appointment. At the same time, **S. W. Kittredge** was named superintendent of the Brainard plant at Larchmont, Ohio, and **V. Zenobile** became chief inspector at Larchmont.

M. E. Nixon has been appointed vice-president, sales, for Canadian Steel Foundries (1956) Ltd. Mr. Nixon joined the Company in 1948 and has been manager of sales for the past two years.

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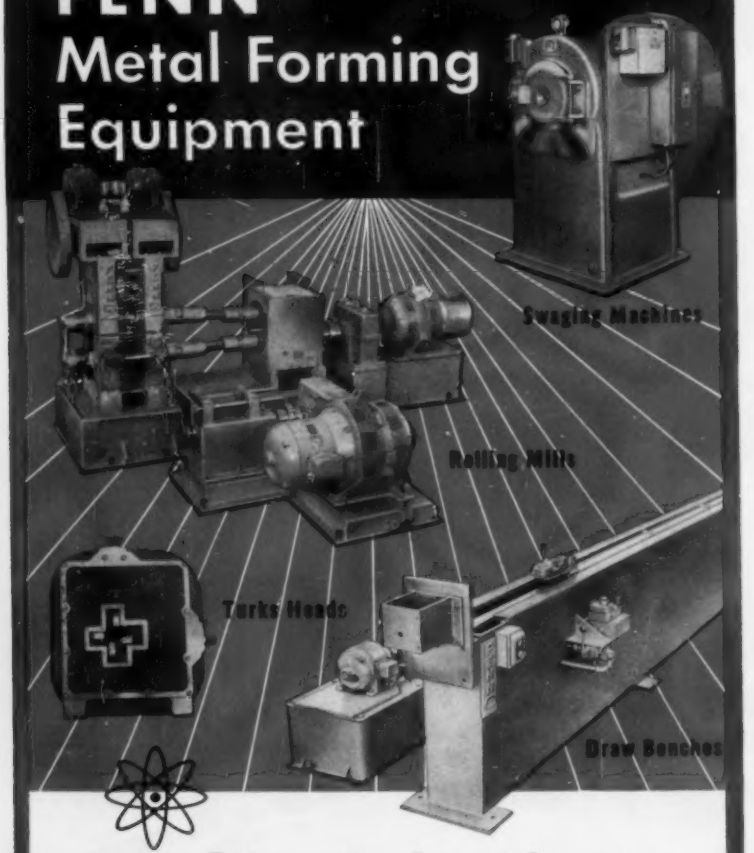

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Personals . . .

Robert H. Bennewitz has accepted an appointment as assistant manager, railroad department, in the Chicago office of the Linde Co., a division of Union Carbide Corp., New York. Mr. Bennewitz joined Linde as a development engineer in 1941 after graduation from the University of Wisconsin, and most recently served in the Kansas City, Mo., office as Southwestern region manager of engineering service.

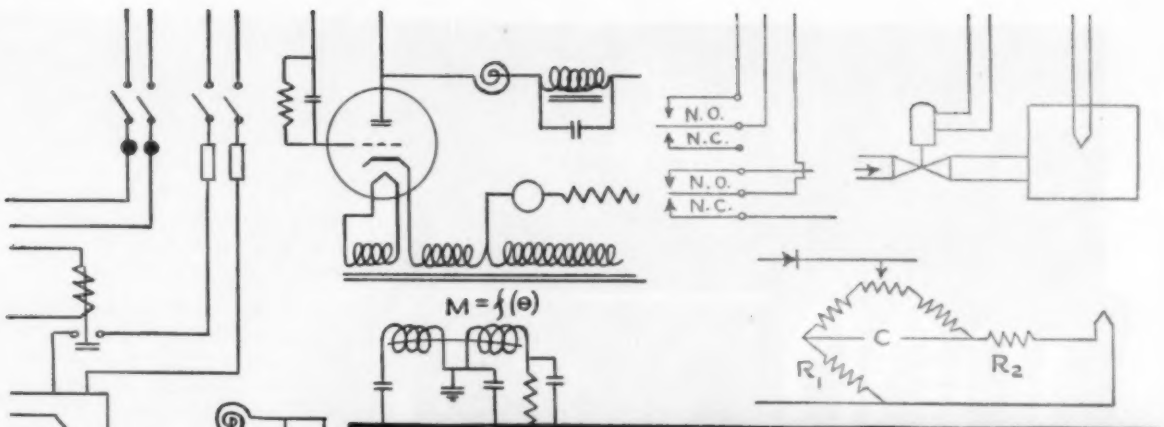
Victor F. J. Horvath is now a mill engineer for the New Jersey Zinc Co. of Pennsylvania.

Donald C. Hilty, manager of research information at the Metals Research Laboratories, Electro Metallurgical Co., Niagara Falls, N.Y., was one of the recipients of the Robert W. Hunt Medal of the American Institute of Mining, Metallurgical, and Petroleum Engineers at the society's recent annual convention in New York. Mr. Hilty was recognized for his work on a paper on iron and steel. **Milton E. Wadsworth** was also one of several authors to be given the Extractive Metallurgy Div. Award of the Metallurgical Society of A.I.M.E. for a technical paper.

Clyde E. Williams recently retired as president of Battelle Memorial Institute, Columbus, Ohio, to form a new company to be known as Clyde Williams and Co. The new firm's aim is to assist the management of industrial concerns with such technical and business problems as research programming and application of science and technology to industry.

Mr. Williams' successor as president of Battelle Memorial Institute is **B. D. Thomas.** Active head of the Institute since being named director a year ago, Dr. Thomas has been a member of the Battelle staff for nearly 25 years.

Philip R. Sperry has accepted a position as project engineer in the aluminum technical center of the metallurgical research division, Olin Mathieson Chemical Corp., New Haven, Conn. He was formerly a research metallurgist with the department of metallurgical research of Kaiser Aluminum & Chemical Corp., in Spokane, Wash.



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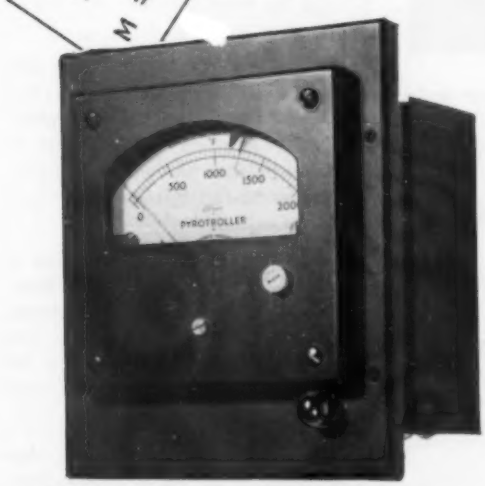

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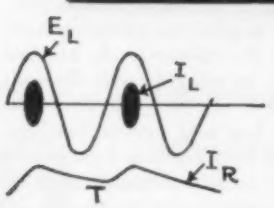
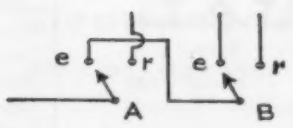
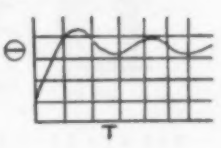
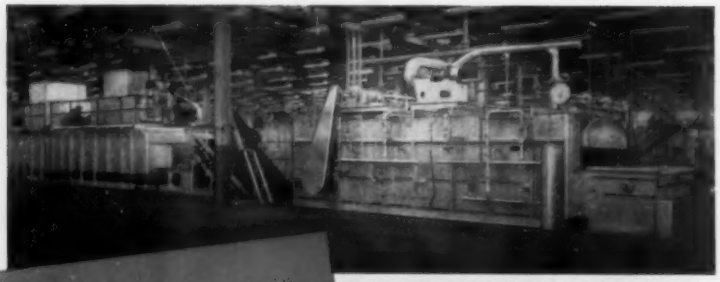
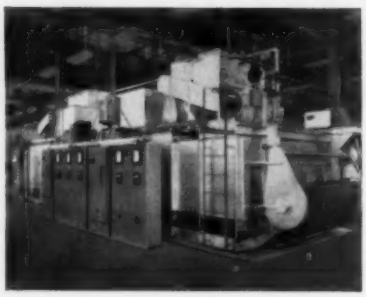








...in Automated Harden Quench and Draw



A large automotive plant required furnaces to heat treat 4,000 lbs. per hour of forgings or castings automatically. The equipment had to be durable to produce a constant uninterrupted flow of parts and also effect a substantial saving over previous methods.

Industrial's direct fired continuous belt type hardening furnace and famous "CIRC-AIR" draw are doing the job. Loading 35 lbs. per square foot of conveyor, hardening is at 1700 deg. F., quench in 1700 gallons of oil and temper at 1200 deg. F.

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PIONEERS AND STILL LEADERS IN RECIRCULATION

Personals . . .

Hugo D. Becker, Jr., has been appointed Southern regional manager for Latrobe Steel Co., Latrobe, Pa., with headquarters in Tampa, Fla. Prior to assuming his new duties, Mr. Becker was a sales representative for Latrobe in Georgia, South Carolina and Florida.

J. K. Hurwitz has accepted a post as senior technologist in spectroscopic research at the Applied Research Laboratory of the U.S. Steel Corp. in Monroeville, Pa. Dr. Hurwitz completed his undergraduate and graduate studies at the University of Toronto, and before coming to the United States was senior scientific officer in the Dept. of Mines and Technical Surveys of the Canadian Government.

Milton C. Parsons recently left his position as chief metallurgist for Burroughs Corp. to accept a post as research metallurgist with Wall Colmonoy Corp., Detroit.

Walter A. Schlegel has been assigned as resident chief metallurgist for the Carpenter Steel Co.'s newly acquired subsidiary, Carpenter Steel of New England, Inc., Bridgeport, Conn. Schlegel joined Carpenter in 1927 after graduation from Dickinson College and since 1954 has been a metallurgist in tool and alloy steels.

George A. Gibbs, formerly affiliated with the Bulova-Watch Co., Inc., has been appointed chief metallurgical engineer and chemist in charge of plant production and quality control for the L-S Plate and Wire Corp., Woodside, N.Y.

Alan C. Mattison, president of Mattison Machine Works, in Rockford, Ill., has been elected second vice-president of the National Machine Tool Builders' Assoc. at the society's annual meeting in French Lick, Ind.

Edward H. Perkins, Jr., vice-president of Brooks & Perkins, Inc., Detroit, is now manufacturing manager of the company. In his new capacity, he will still retain the management of the Magplate Div. Mr. Perkins has held various executive positions with Brooks & Perkin, most recently as administrative assistant to the executive vice-president.

2500 pound ingot of titanium cast in a single mold using ti sponge as the consumable electrode.

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melt buttons, pounds, or tons in proved vacuum arc furnaces

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You can now produce melts in vacuum or a controlled atmosphere—in ingots up to 24″ diameter and larger—of steel, zirconium, titanium, and high melting point alloys. You can produce melts of very high purity and superior grain structure; for example: titanium with hydrogen levels held to 0.0012 wt.% and Brinell hardness values between 95 and 105.

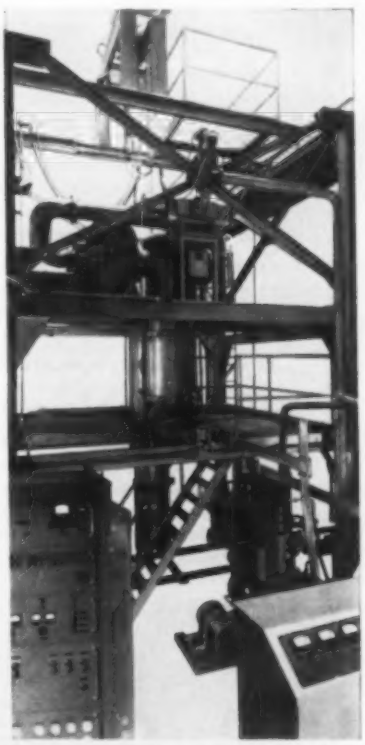
Unique electrode feed. The high quality of the melts is attained by feeding the consumable* electrodes at optimum rates. An electronic system, the Heratron Control, monitors arc voltage, current, and short circuits—and automatically maintains the arc between ½ and 1 inch in length.

Maintaining the vacuum. Each pumping system is assembled from the world's largest selection of CEC vapor pumps, Roots pumps, and other mechanical pumps. Whether your specifications call for a diffusion-ejector pump plus a Roots pump or a Roots pump plus another mechanical pump, CEC can provide the very finest together with the necessary vacuum controls, gauges, valves, and piping.

How to purchase. There are five standard models of the Heraeus furnace with capacities from 20 lbs. to 6600 lbs. of steel—and special designs with capacities ranging up to and beyond 10,000 lbs. of steel.

CEC has an exclusive license to sell and service these furnaces, the Roots pumps, and accessories. For a complete discussion of these proved furnaces, write for Bulletin 4-27.

*The smallest of these furnaces also operate with nonconsumable electrodes



Ingots of 16″ diameter can be processed in this Model VA-L 600 sh Heraeus furnace.

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you can get this brilliant finish directly on zinc die castings!

No electroplating--no mechanical finishing!

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NEW IRIDITE® (Cast-Zinc-Brite)

brightens zinc die castings by chemical polishing, protects against corrosion

NOW, FOR THE FIRST TIME you can get a brilliant, decorative finish directly on zinc die-cast parts . . . without mechanical finishing, without electroplating! The luster is provided by the *chemical polishing* action of new Iridite (Cast-Zinc-Brite) solution. Even surface blemishes, such as cold shuts, are brightened by this new process. No electrolysis. No special equipment. No specially trained personnel. Just a simple chemical dip for a few seconds and the job is done. And, this new Iridite has been *tested and proved* in production.

CORROSION RESISTANCE, TOO! New Iridite (Cast-Zinc-Brite) provides exceptional corrosion resistance for bright-type chromate finishes . . . also guards against blueing or darkening by eliminating zinc plate formerly required in bright chromate finishing of zinc die castings.

AS A BASE FOR ELECTROPLATING—Lower mechanical finishing costs are possible where plated finishes are *required* since the brightness provided by this new Iridite may be sufficient.

LET US SHOW YOU what Iridite (Cast-Zinc-Brite) can do for you. Send us at least a half-dozen typical zinc die-cast parts for FREE PROCESSING for your own tests and evaluation. Or, for immediate information, call in your Iridite Field Engineer. He's listed under "Plating Supplies" in your classified 'phone book. *IMPORTANT: when you give us samples for test processing, please be sure to identify the alloy used.*

Iridite is approved under government specifications

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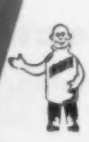
Manufacturers of Iridite Finishes for Corrosion Protection and Paint Systems on Non-Ferrous Metals; ARP Plating Chemicals



Personals . . .

Leon B. Rosseau was elected president and treasurer of the Ajax Electric Co., Philadelphia, at a recent meeting of the board of directors. Associated with Ajax for over 17 years, Mr. Rosseau was vice-president and general manager until taking over his new assignment. He succeeds **John E. Haig**, one of the founders of the company, who has retired after 27 years in the business. Mr. Haig will continue to serve Ajax on a consulting basis. **H. W. Schrader**, formerly production manager, was named vice-president at the same meeting.

Richard D. Mercer has been assigned as product manager, stainless steel strip, in the sales department of Allegheny Ludlum Steel Corp., Pittsburgh. Since joining Allegheny Ludlum in 1950, he has served as salesman in the Chicago, Dayton and Cincinnati offices, and two years ago was appointed assistant to the director of sales, stainless and specialty steels.

Harold D. Kessler, formerly in charge of the metallurgical research division of Titanium Metals Corp. of America in Henderson, Nev., has been transferred to the company's newly established product development laboratory in Toronto, Ohio, where he will head the new product development division of the technical department. Several other members were transferred to the new laboratory. **W. M. Parris** will be in charge of sheet and strip development, **E. Bohanek** will head the bar, billet, extrusions, and wire department, and **A. Smith** will head the laboratory operations.

Leo P. Tarasov has been appointed research associate for the Norton Co., Worcester, Mass. A graduate of Case Institute of Technology and Massachusetts Institute of Technology, he has been a member of the research and development department of the company since 1941.

G. L. McMillin has been appointed president and general manager of the Canadian Steel Foundries (1956), Ltd., Montreal. Until recently, he was vice-president and general manager of Canadian Steel Foundries.

typical large drill bit

Surface metal is cut away to shape drill point and spiral flutes — core is exposed to wear, structural loads

Point and cutting lips are critical to drill performance. If alloy has any weakness at center, poor cutting or broken drill will result. Mel-Trol helps to solve this problem by providing greater strength and toughness at the core. Never before have commercially available alloys been as free of segregation, porosity and centerline weakness.

MEL-TROL®... alleviates a major metalworking problem– poor centerline quality in alloys

The more surface metal you cut away from an alloy steel bar, the more important uniform core quality becomes. The drill illustration above shows you why.

In alloy steels made by conventional steelmaking process, segregation, porosity or other inhomogeneities are often found along the centerline. Result: the core metal lacks the toughness of the rest of the bar, even though it may show no detectable variation.

To alleviate this major cause of poor tool quality, poor tool life and excessive rejects, Carpenter metallurgists developed the Mel-Trol process. Now, for the first time, alloys with greater uniformity from surface to centerline are being made in quantity.

The Mel-Trol process provides greater freedom from segregation, porosity and centerline weakness through a system of quality controls which play a part in every phase of the entire steelmaking process. Equipment developed specifically for Carpenter is used together with the most modern standard quality control tools. Every piece of equipment is used to its highest accuracy—nothing less.

Mel-Trol alloys are now available at Carpenter mill-branch warehouses. Ask about them the next time a Carpenter representative calls on you. He'll show you how you can join the growing number of companies who are finding Mel-Trol alloys the answer to a host of metalworking problems.

Carpenter STEEL

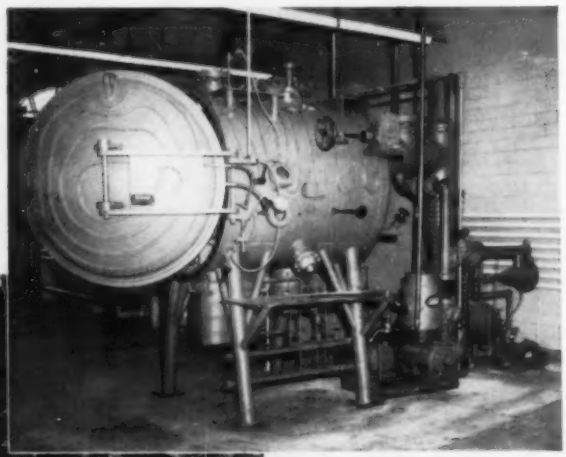
The Carpenter Steel Company, 133 W. Bern St., Reading, Pa.
Export Dept.: The Carpenter Steel Co., Port Washington, N. Y.—"CARSTEELCO"

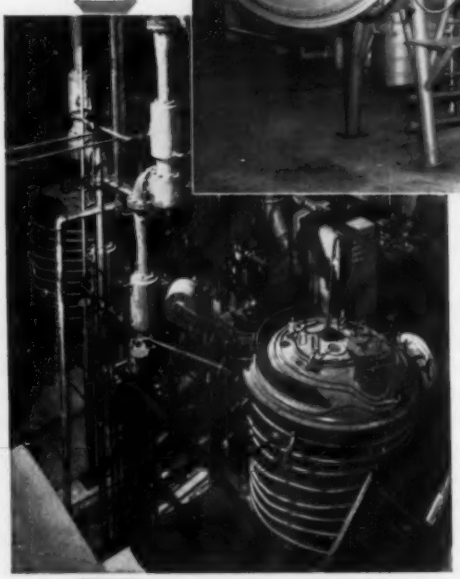
Pioneering in improved specialty steels through continuing research

Kinney®

HIGH VACUUM FURNACES

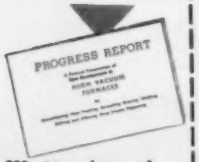
The increasing demand for metals of high purity is now well beyond a few specialized applications. The obvious improvements in the properties of the metal on the one hand—and, the superior end product with minimum rejects, on the other, spell out the need for advanced type furnace equipment NOW! KINNEY High Vacuum Furnaces are exciting high interest among metallurgists both through their performance and the insight of your problem exhibited in their engineering! Whether your interests lie solely in ferrous metals or any of the so-called "exotic" group, you will want to know more about *What Kinney is Doing.*





ABOVE
300 lb. KINNEY High Vacuum Melting Furnace built for D. E. Makepeace, Div. of Engelhard Industries, Inc., Plainville, Mass. This equipment, with induction heating, is used for Vacuum Melting Uranium and its alloys and is designed for either tilt or bottom pouring. The resulting vacuum processed metal is used in the fabrication of Nuclear fuel elements.

LEFT
Two KINNEY High Vacuum Furnaces in the plant of The Brush Beryllium Co., Elmore, Ohio. These 300 lb. units are used for melting and purifying Beryllium. The tilting furnace chambers accommodate special induction heated crucibles.



Write for the Progress Report on new developments in Kinney Furnaces.

KINNEY MFG. DIVISION
THE NEW YORK AIR BRAKE COMPANY
3584C WASHINGTON STREET • BOSTON 30 • MASS.

Please send me copy of your Progress Report on High Vacuum Furnaces.

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Personals . . .

Philip Cohen has joined Magnetics, Inc., Butler, Pa., as manager of a group conducting research on high-permeability magnetic materials. Dr. Cohen was on the staff of the General Electric Co. in Cincinnati, Ohio, before coming to Magnetics, Inc.

Burton C. Person has left his position as assistant chairman of the John Wood Co. to accept a post as plant manager of Modiglass Fibers, Inc., in Bremen, Ohio.

Michael Soviak has been placed in charge of the metallurgical control programs of Commercial Steel Treating Corp., Detroit, as chief metallurgist. He had served as assistant chief metallurgist since joining the company in 1946.

Bruce R. Wise has been transferred to the Cincinnati, Ohio, office of the Timken Roller Bearing Co. as sales engineer in the steel and tube division. Beginning his career with the company as a sales trainee in 1953, he had been sales engineer in the Los Angeles district office since 1954. **Robert Winder** has succeeded Mr. Wise as sales engineer in the Los Angeles district of the steel and tube division. Since joining the company in 1956, he has served as sales engineer in the Detroit office.

Robert A. Lubker has been named director of research of Alan Wood Steel Co., Philadelphia, where he will be in charge of developing a new research laboratory for the company. For the past ten years, Mr. Lubker has been associated with the Armour Research Foundation of Illinois Institute of Technology, and last held the post of manager of metals research there.

Carl E. Applequist has assumed new responsibilities as manager of steel sales for International Harvester Co., Chicago. He joined the organization in 1930 as a steel sales representative.

George B. Michie, vice-president and public relations director of Electro Refractories & Abrasives Corp., Buffalo, N.Y., has been selected as a member of the public relations committee of the Grinding Wheel Institute.

Chemical Prepaint Treatments for Metal Surfaces

What they do, the types available, how they are applied

By J. H. GEYER
Manager, Product Development Dept.,
AMERICAN CHEMICAL PAINT COMPANY

Paint systems have been steadily improved in an effort to produce more decorative, easier-to-apply, and more corrosion-resistant films. The ability, however, of any paint film to perform its predetermined functions cannot be fully utilized without properly preparing the metal surface.

The prepaint preparation of the metal surface is therefore a highly important part of the system. Chemical prepaint treatments are designed to do four jobs and do them well. First, they remove organic soils, shop dirt, scale, and rust or corrosion products from the metal surface. Second, they provide surfaces that are completely compatible with subsequent paint films. Third, they produce a *tooth* that promotes good paint film adhesion. Fourth, they effectively prevent underpaint corrosion growth after any breakthrough in the paint film.

Basically, there are four types of chemical prepaint treatments. These are phosphoric acid, iron phosphate, zinc phosphate, and amorphous phosphate or chromate. Each is discussed briefly in the following paragraphs.

Phosphoric Acid

Perhaps the most widely used and certainly one of the most economical chemical prepaint treatments is the phosphoric acid cleaner combination materials. ACP Deoxidine® is such a material. It removes organic soils, rust, scale and contaminating elements from the metal surface. It also produces a light etch on steel, aluminum or zinc surfaces which considerably aids in increasing paint adhesion. It does not, however, form an actual coating on the metal surface. Any breakthrough in the subsequent paint film will permit underfilm corrosion to proceed. Grades of Deoxidine are available for application by brush or swab, hot and cold dip, or hot spray.

Iron Phosphate

Iron phosphating processes are extensively used in the chemical prepaint treatment of appliances such as water heater shells, ranges, washers, dryers and other *white lines*. These processes will produce excellent paint-bonding films on the metal and retard or prevent underpaint corrosion. Duridine,® ACP's iron phosphating process, is a combination organic soil cleaner and iron phosphate coating material. Both the cleaning and coating operations take place in the same bath. Duridine and other iron phosphates do not lend themselves to brush-on application, are primarily designed for spray type equipment of four or five stages. But several dip installations are successfully operating today by inclusion of an alkali precleaning stage.

Zinc Phosphate

ACP Granodine® is an example of this type of chemical prepaint treatment process, the type now being used to treat steel in the automotive industry, and predominantly specified for steel ordnance and military items. This process forms a coating which offers the ultimate in paint adhesion promotion and vastly augments the corrosion resistance of subsequent paint films. Zinc phosphate materials are extremely flexible as to method of application—can be applied by brush, dip or automatic spray equipment. In a typical dip or power spray system, the stages would be alkali clean, water rinse, zinc phosphate treatment, water rinse, and acidulated final rinse. If the metal has considerable areas of rust or scale, an acid pickle is advisable following the alkali cleaning stage.

On zinc surfaces, the zinc phosphates perform a rather unique function. They act as a barrier against chemical reaction between the applied paint film and the zinc surface. This effectively prevents blistering of the paint and early breakdown of the film. This is in addition, of course, to the improvement of paint adhesion and the retarding of underpaint corrosion. ACP Lithoform® is specially designed for use over zinc surfaces and finds wide application as a prepaint treatment for ornamental zinc die castings, refrigerator liners, and on most galvanized work requiring painted finishes.

Amorphous Phosphate and Chromate

These coatings are the films produced by the ACP Alodine processes and similar ones on aluminum surfaces. They have met with wide acceptance in the prepaint treatment of venetian blind strips, refrigerator liners, aluminum heat transfer units, aircraft sheet metal assemblies, and many other items fabricated from aluminum. The various coatings provide an excellent film for the promotion of paint adhesion and effectively prevent underfilm corrosion. As in the case of zinc, aluminum exhibits a tendency to chemically react with some paint systems. The Alodine processes develop a barrier film between the paint and the aluminum surfaces which prevents this reaction. The Alodines are extremely versatile materials that can be applied to aluminum surfaces by brush, hand spray, dipping, mechanical spraying, or roller coating equipment. Brush application is particularly well adapted to the processing of parts too large for simple dip systems or in manufacturing operations that do not warrant a tank setup. In dip, spray or roller coating application, the system usually consists of an alkaline preclean, a water rinse, the Alodine treatment, a water rinse, and an acidulated final rinse. Where the surface is heavily oxidized, a deoxidizer in the line is needed.

The major chemical prepaint treatments for metals have been covered briefly in this article. More complete information can be had by contacting an ACP sales representative or by writing us at Ambler, Pa.

CHEMICALS ACP PROCESSES
AMERICAN CHEMICAL PAINT COMPANY
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New Chemical Horizons for Industry and Agriculture

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Looking for the world's most complete stock of 52100 steel tubes and bars? You've come to the right spot . . . . . .

PETERSON STEELS, INC.
Union, New Jersey
Detroit, Michigan Chicago, Illinois

Personals . . .

Michael L. McGinnis has joined the materials engineering division of the Gulf Research and Development Co., Harmarville, Pa.

Adam M. Steever has resigned his position with Columbia Tool Steel Co., Chicago Heights, Ill., to retire to Florida.

John E. Jacobs has been promoted from assistant general manager to general manager of the Bethlehem Steel Co. plant in Lackawana, N.Y. Joining the company in 1935 at the main works in Bethlehem, Pa., he was transferred to the Lackawana plant a year later, and since 1950 had served as assistant general manager.

Jestyn Williams has retired from his position with Gear Specialties, Inc., Chicago, and is now living in Georgia.

Rudolf H. Thielemann, chairman of Stanford Research Institute's metallurgy department, has been reappointed chairman of the Subcommittee on Power Plant Materials of the National Advisory Committee for Aeronautics for 1958. Mr. Thielemann, who has been a member of the subcommittee since 1947, was also reappointed to membership on the Committee on Power Plants for Aircraft.

Mrs. Laurence D. Pellier has accepted a position as applications chemist for Norelco Instruments Div., Philips Electronics, Inc., Mount Vernon, N.Y., where she will devote her attention to technical problems involving electron microscope techniques. Until taking over her new assignment, Mrs. Pellier was a research metallurgist for Sigmund Cohn Corp., Mount Vernon, N.Y., and prior to that time was a metallurgist with American Cyanamid Corp., Stamford, Conn.

Ernest R. Ramirez has been named research engineer in the metallurgical products department of General Electric Co., Detroit, assigned to work on the special inorganic materials project in the advance engineering subsection. Dr. Ramirez formerly conducted research on the surface finishing of aluminum alloys for the Reynolds Metals Co.

How the purity of Electromanganese® eliminates steel-making "bargains" that cost money

In theory few metallurgists will argue that pure Electromanganese® makes a better steel additive than manganese alloys that are contaminated with elements detrimental to the finished product.

In practice, however, metallurgists may frequently choose alloys that contain the manganese they want as well as elements they don't want, can't use, and would be better off without! *Their reason*: it's cheaper! *Their problem*: getting rid of the undesirable elements . . . if they can. *The result*: for the most part, adequate but less-than-the-best quality in the finished product.

But let's take a *good* look at the price tag. Are contaminated manganese alloys really cheaper than the pure element? Today's cost difference between other manganese alloys and pure Electromanganese is only a few pennies. This small differential is easily overcome. For example, commercial use of carbon- and silicon-free Electromanganese in low carbon aluminum killed sheet steel shows potential economic and quality advantages in the following areas:

1. Improved furnace and deoxidation practice
2. Improved deep drawing characteristics
3. Improved sheet quality; i.e., fewer surface rejections

RESULT: better quality at lower cost for you and your customers.

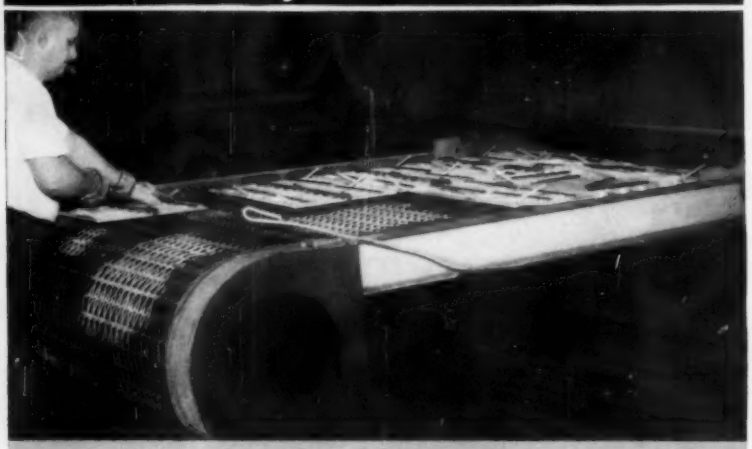
When you buy Electromanganese—Foote's electrolytic manganese, guaranteed 99.9% pure—you improve steel quality, cut down rejects, and end up with real dollars-and-cents savings. A Foote engineering representative is ready to tell you about actual case histories in other plants . . . help you work out what you might expect in your own. Until then, Bulletin 201 will give you more details on Electromanganese, the special Hydrogen-Removed Grade (H:7.5ppm), and Nitrided Grades.

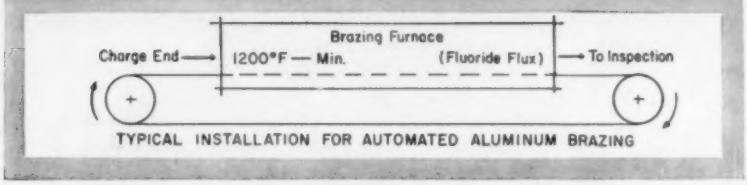
Write Technical Literature Department, Foote Mineral Co., 24 Eighteen West Chelten Building, Philadelphia 44, Pa.

Foote MINERAL COMPANY

ELECTROLYTIC MANGANESE METAL • NITRELMANG • HYDROGEN-REMOVED ELECTROMANGANESE • RIMEX MANGANESE SULPHIDE • WELDING GRADE FERRO ALLOYS • COMMERCIAL MINERALS AND ORES LITHIUM METAL, CHEMICALS, MINERALS • ZIRCONIUM, TITANIUM, HAFNIUM (IODIDE PROCESS)

Cambridge WOVEN WIRE BELTS





TYPICAL INSTALLATION FOR AUTOMATED ALUMINUM BRAZING

METAL-MESH BELT CONTROLS PRODUCT UNIFORMITY IN CONTINUOUS BRAZING

Here's a belt that not only shrugs off hot atmospheres and corrosive fluxes, but helps produce uniformly brazed parts continuously —and in less time. Moving through the furnace at a controlled speed, the all-metal Cambridge Belt allows the atmosphere to circulate freely through its open mesh and around the product for fast, thorough treatment.

In heat treating, cleaning or quenching operations, too, Cambridge Belts help maintain capacity production and cut operating costs. Here's how:

CONTINUOUSLY MOVING BELTS ELIMINATE BATCH PROCESSING—give faster, more economical production; reduce manual handling.

ALL-METAL CONSTRUCTION IS HEATPROOF, COLDPROOF, ACIDPROOF—Cambridge belts can be woven from any metal or alloy to take sub-zero or up to 2100° F. temperatures, yet remain impervious to corrosive atmospheres or solutions.

OPEN MESH PROVIDES FREE AIR, LIQUID CIRCULATION—gives more uniform processing of product; grit, sand, quench solutions drain through belt immediately.

SPECIAL SURFACE ATTACHMENTS AVAILABLE—raised edges or cross flights hold product on belt during movement.

Talk to your Cambridge Field Engineer soon—he'll explain the many advantages of continuous heat treating on Cambridge Woven Wire Belts. He'll recommend the belt size, mesh or weave—and the metal or alloy—best suited to your operations. You'll find his name in the classified phone book under "BELTING, MECHANICAL." Or, write for FREE 130-PAGE REFERENCE MANUAL giving mesh specifications, design information and metallurgical data.

The Cambridge Wire Cloth Co.

WIRE CLOTH | METAL-MESH CONVEYOR BELTS | WIRE CLOTH FABRICATIONS

Department B, Cambridge 3, Maryland

OFFICES IN PRINCIPAL INDUSTRIAL CITIES

Personals . . .

Gordon E. Grotke has been appointed a technologist in the welding section of the bar, plate and forged products division of the U. S. Steel Corp. Applied Research Laboratory in Monroeville, Pa. A graduate of Rensselaer Polytechnic Institute, Mr. Grotke was formerly affiliated with Sciaky Bros. Research Laboratory, Los Angeles.

Albert P. Gagnebin and **L. E. Grubb** were recently named assistant vice-presidents of the International Nickel Co., Inc., New York. Mr. Gagnebin will continue as manager of the nickel sales department while Mr. Grubb will be placed in charge of labor relations in all Inco plants in the United States. He was general superintendent of the Huntington, W. Va., works from 1953 until his transfer to New York.

Cord H. Sump has left Armour Research Foundation of Illinois Institute of Technology to accept an appointment as research director of Goldsmith Bros. Smelting & Refining Co., Chicago, Ill. Mr. Sump was with the Armour Research Foundation for seven years as research metallurgist and supervisor of powder and fiber metallurgy research.

W. Paul Gerhart, metallurgical engineer for Bethlehem Steel Co., Bethlehem, Pa., has announced his retirement. Mr. Gerhart began his metallurgical career with the Worth Steel Co., which later merged with Bethlehem Steel, and has served in various plants of the company. Since 1940 he has been in the steel division as assistant metallurgical engineer and later as metallurgical engineer in charge of plates, structural shapes, piling bars and fabricated parts. Mr. Gerhart will be succeeded by **John R. LeCron**, assistant metallurgical engineer. Mr. LeCron joined the company in 1930 after graduation from Swarthmore College and since 1949 has been assistant metallurgical engineer at the Bethlehem plant.

A. P. Spooner has retired as metallurgical engineer for Bethlehem Steel Co., Bethlehem, Pa.

S. B. Knutson is now plant development engineer for D. E. Makepeace Co., Attleboro, Mass.

The legendary Firebird, the Phoenix, rose young and strong again and again from flames . . . This is the new Norton Firebird — symbol for the exciting new fused materials made in Norton's electric furnaces.

BORON: gift of the Firebird

Comparable to the ancient Firebird legend is the wonder-working energy of Norton electric furnaces. Here, raw materials are transformed into new, high-purity compounds of tremendous importance to scientific and industrial progress.

For example, Norton began development of stable boron compounds a quarter century ago and now provides boron as the nitride, the carbide or as borides and experimentally in its elemental form.

Norton electrochemical engineering may be a valuable aid to your own processing. It enables users to improve manufacture with an increasing variety of boron-rich compounds, including intermediates for chemical processing and additives for metal alloying. Technical cooperation is available with all these *Gifts of the Firebird.*

Gifts of the Firebird: compounds of silicon • zirconium • boron • aluminum • magnesium • titanium • chromium . . . . . including many borides • carbides • nitrides • oxides.

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CATALOG AVAILABLE

Write to NORTON COMPANY, Electrochemical Division, 802 New Bond Street, Worcester 6, Massachusetts.

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MAKING BETTER PRODUCTS . . . TO MAKE YOUR PRODUCTS BETTER

Digests of Important Articles

Induction Hardening of Bearing Surfaces

Digest of "Induction Hardening as a Means of Increasing the Resistance to Wear of Internal Combustion Engines and Machinery", by G. W. Seulen, *Metal Treatment and Drop Forging*, Vol. 23, August 1956, p. 305-310.

IN MANY INSTANCES the induction hardening process is replacing the processes of carburizing, nitriding and flame hardening for improving the wear resistance of bearing surfaces.

Resistance to electric currents which are induced into the surface causes heating; when suitable temperatures are reached, the part is quenched, and the surface attains a high degree of hardness.

Penetration of the energy is related to frequency, density of current, time of heating, and properties of the material. For example, an increase in the heating time with a reduction in the density results in an increase in the depth of hardening due to heat flow by conduction. Other factors which increase the depth of penetration are the increase in electrical resistance and the decrease in magnetic permeability which occur with rising temperatures. The current steadily shifts to layers beneath the surface.

Thin-walled sections can be only shallow hardened if they are to retain adequately tough core material. However, deep hardened zones are necessary to withstand heavy bearing pressures.

The carbon content of steels used for induction hardening varies from 0.35 to 0.55%. Below this range adequate hardness cannot be produced and above it there is a greater risk of cracking. Alloys are used to increase hardenability and improve the physical properties of the core. Since the heating time is rarely more than a few seconds, a structure which will permit rapid carbide solution is necessary. However, the high temperatures permit the use of slightly sluggish structures without the danger of increasing grain size. Normalizing is often necessary to produce desired physical properties in the core.

Depending upon the shape and size of the parts being treated, the induction hardening method may be "static" or "progressive". With "static" hardening the entire surface is heated and quenched at one time. In the "progressive" method (generally applied to long objects) a narrow band is heated and moved along the length of the part; quenching follows the inductor. Rotation of the part is desirable during heating to obtain uniformity. Occasionally inductors which partially surround a bearing and through which the part is rotated are necessary; rotation is then essential in order to bring the entire surface up to hardening temperature. Rotation to assure a uniform quench is recommended – this avoids soft spots. Rotation during the progressive hardening process also keeps distortion at a minimum. In fact, if the parts are processed horizontally, rotating is absolutely necessary.

To use available electric capacity to its fullest extent, select equipment to use a frequency which will be satisfactory under the shortest time cycle applicable. In general, low frequency is used for deep hardening and high frequency for shallow hardening.

In addition to the static and progressive methods, a "linear" technique is used when treating extensive continuous surfaces. For example, the wearing surface of a railroad wheel can be rotated slowly past a specially designed inductor which will progressively heat and quench a narrow area across the surface. This linear method causes an overlap of lower hardness at the starting point. The size of this zone is determined by the construction of the inductor and the design of the quench head. This technique is not suitable for crank pins and parts which require complete surface hardening.

Water is generally employed for quenching; however, oil-water mixtures and conventional quenching oils can also be used. In progressive hardening processes, the use of oil creates a fire hazard due to the accumulation of oil vapor.

When designing parts to be induction hardened, abrupt changes of section should be avoided whenever possible, the wall thickness of thin sections should be as regular as possible, collars and shoulders should have liberal radii, and holes and grooves should be well finished on the edges.

Since the induction hardening process can be performed essentially in the final production line, induction hardening equipment as produced today is essentially a machine tool.

H. B. OSBORN, JR.

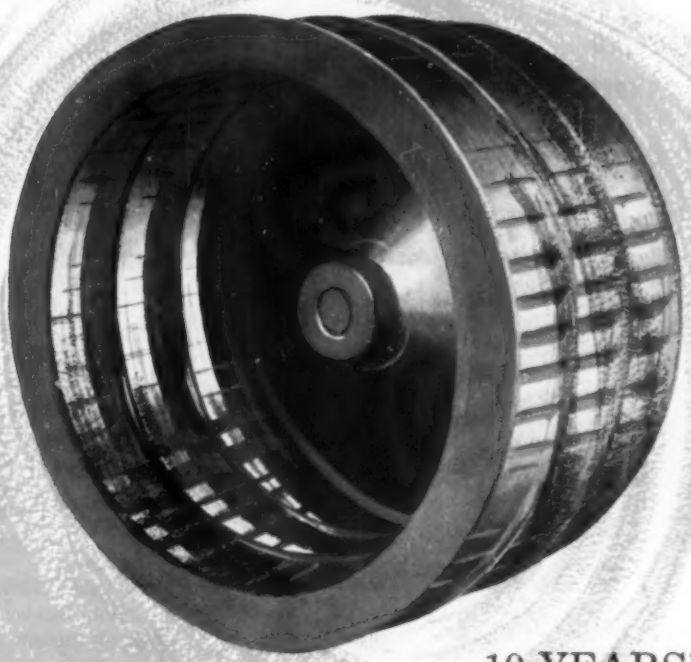
Stress-Rupture of Heat Resistant Alloys

Digest of "Notch and Smooth Bar Stress-Rupture Characteristics of Several Heat Resistant Alloys in the Temperature Range Between 600 and 1000° F.", by J. G. Sessler and W. F. Brown, Jr., A.S.T.M. Preprint No. 76, 1956, 15 p.

IN THE temperature range 600 to 1000° F. – too high to allow the use of aluminum or titanium but not high enough to require the use of the very costly superalloys – the ferritic heat resistant steels may compete

(*Continued on page* 130)

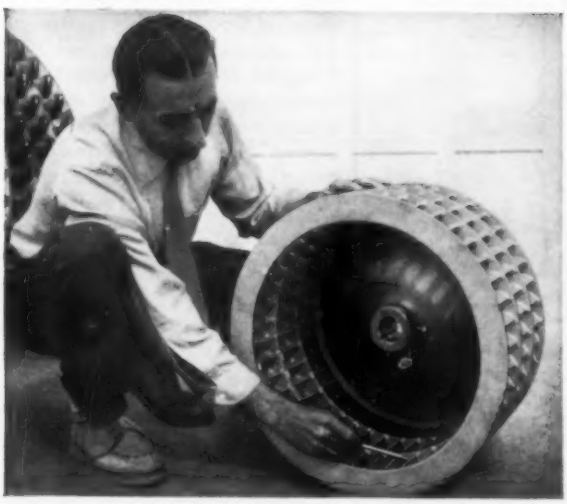
HAYNES Alloys solve the *tough* heat problems



10 YEARS' SERVICE at 1600 to 1800 deg. F.

Fans with impellers or rotors made of MULTIMET alloy circulate the atmosphere inside heat-treating furnaces and are exposed to temperatures from 1600 to 1800 deg. F. They withstand both reducing and oxidizing conditions produced during cyaniding, annealing, and nitriding operations. Their average life is about 10 years.

MULTIMET is one of 12 HAYNES alloys specifically designed for use where strength at high temperatures is essential. For details on properties, forms, and prices send for descriptive literature or contact our nearest sales office. HAYNES STELLITE COMPANY, Division of Union Carbide Corporation, General Offices and Works, Kokomo, Indiana. Sales Offices in Chicago, Cleveland, Detroit, Houston, Los Angeles, New York, San Francisco.



Designed to operate at 1800 deg. F., this impeller has 180 blades formed from MULTIMET alloy sheet. Impellers range from 12 to 48 inches in diameter. Furnace rotors, cast of MULTIMET alloy, operate at temperatures up to 2100 deg. F.

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Digests of Important Articles

Induction Hardening of Bearing Surfaces

Digest of "Induction Hardening as a Means of Increasing the Resistance to Wear of Internal Combustion Engines and Machinery", by G. W. Seulen, *Metal Treatment and Drop Forging*, Vol. 23, August 1956, p. 305-310.

IN MANY INSTANCES the induction hardening process is replacing the processes of carburizing, nitriding and flame hardening for improving the wear resistance of bearing surfaces.

Resistance to electric currents which are induced into the surface causes heating; when suitable temperatures are reached, the part is quenched, and the surface attains a high degree of hardness.

Penetration of the energy is related to frequency, density of current, time of heating, and properties of the material. For example, an increase in the heating time with a reduction in the density results in an increase in the depth of hardening due to heat flow by conduction. Other factors which increase the depth of penetration are the increase in electrical resistance and the decrease in magnetic permeability which occur with rising temperatures. The current steadily shifts to layers beneath the surface.

Thin-walled sections can be only shallow hardened if they are to retain adequately tough core material. However, deep hardened zones are necessary to withstand heavy bearing pressures.

The carbon content of steels used for induction hardening varies from 0.35 to 0.55%. Below this range adequate hardness cannot be produced and above it there is a greater risk of cracking. Alloys are used to increase hardenability and improve the physical properties of the core. Since the heating time is rarely more than a few seconds, a structure which will permit rapid carbide solution is necessary. However, the high temperatures permit the use of slightly sluggish structures without the danger of increasing grain size. Normalizing is often necessary to produce desired physical properties in the core.

Depending upon the shape and size of the parts being treated, the induction hardening method may be "static" or "progressive". With "static" hardening the entire surface is heated and quenched at one time. In the "progressive" method (generally applied to long objects) a narrow band is heated and moved along the length of the part; quenching follows the inductor. Rotation of the part is desirable during heating to obtain uniformity. Occasionally inductors which partially surround a bearing and through which the part is rotated are necessary; rotation is then essential in order to bring the entire surface up to hardening temperature. Rotation to assure a uniform quench is recommended – this avoids soft spots. Rotation during the progressive hardening process also keeps distortion at a minimum. In fact, if the parts are processed horizontally, rotating is absolutely necessary.

To use available electric capacity to its fullest extent, select equipment to use a frequency which will be satisfactory under the shortest time cycle applicable. In general, low frequency is used for deep hardening and high frequency for shallow hardening.

In addition to the static and progressive methods, a "linear" technique is used when treating extensive continuous surfaces. For example, the wearing surface of a railroad wheel can be rotated slowly past a specially designed inductor which will progressively heat and quench a narrow area across the surface. This linear method causes an overlap of lower hardness at the starting point. The size of this zone is determined by the construction of the inductor and the design of the quench head. This technique is not suitable for crank pins and parts which require complete surface hardening.

Water is generally employed for quenching; however, oil-water mixtures and conventional quenching oils can also be used. In progressive hardening processes, the use of oil creates a fire hazard due to the accumulation of oil vapor.

When designing parts to be induction hardened, abrupt changes of section should be avoided whenever possible, the wall thickness of thin sections should be as regular as possible, collars and shoulders should have liberal radii, and holes and grooves should be well finished on the edges.

Since the induction hardening process can be performed essentially in the final production line, induction hardening equipment as produced today is essentially a machine tool.

H. B. OSBORN, JR.

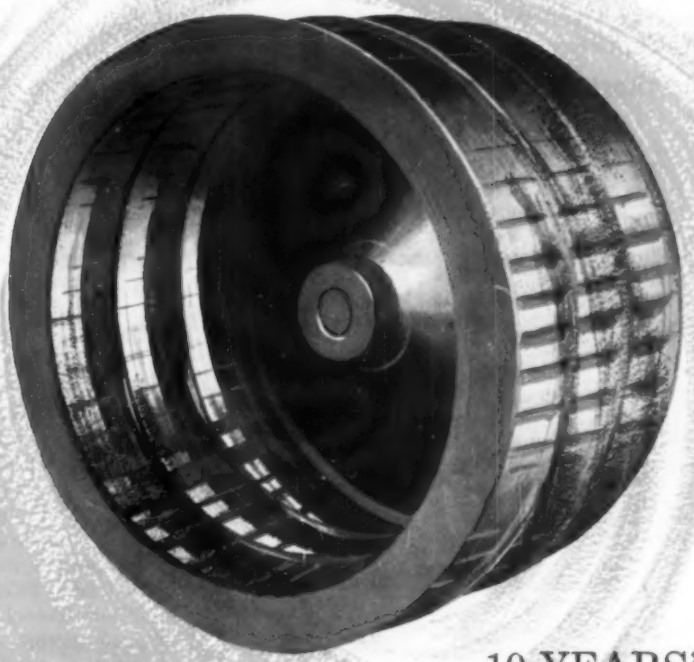
Stress-Rupture of Heat Resistant Alloys

Digest of "Notch and Smooth Bar Stress-Rupture Characteristics of Several Heat Resistant Alloys in the Temperature Range Between 600 and 1000° F.", by J. G. Sessler and W. F. Brown, Jr., A.S.T.M. Preprint No. 76, 1956, 15 p.

IN THE temperature range 600 to 1000° F. – too high to allow the use of aluminum or titanium but not high enough to require the use of the very costly superalloys – the ferritic heat resistant steels may compete

(*Continued on page* 130)

HAYNES Alloys solve the *tough* heat problems



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Designed to operate at 1800 deg. F., this impeller has 180 blades formed from MULTIMET alloy sheet. Impellers range from 12 to 48 inches in diameter. Furnace rotors, cast of MULTIMET alloy, operate at temperatures up to 2100 deg. F.

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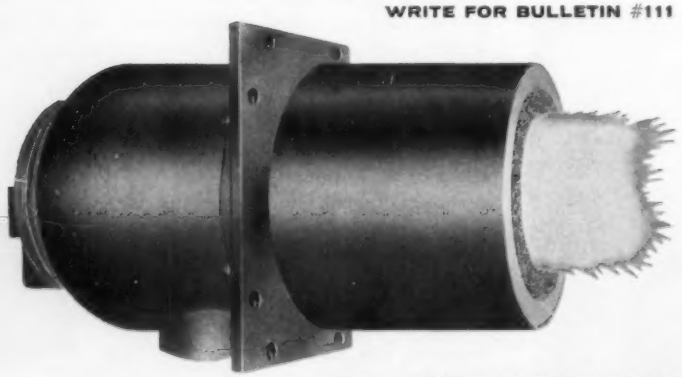

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Stress-Rupture . . .

with the superalloys. If the temperature is low enough, the ferritic materials may offer certain strength advantages.

Alloys are chosen to represent four classes of creep resistant materials, as follows:

1. Low-alloy steels, represented by 17-22 A (S).

2. Martensitic stainless steels, represented by A.I.S.I. 410 and A.M.S. 5616.

3. Modified ferritic chromium stainless steels, represented by 17-4 PH.

4. Superalloys, represented by A-286 and Inconel "X".

Tests determined (*a*) stress-rupture data between 0.1 and 1000 hr. at temperatures between 600 and 800° F., (*b*) the influence of sharp notches on the rupture strength, and (*c*) possible strength limitations at moderately elevated temperatures.

Both Inconel "X" and A-286 indicated rupture strengths which are essentially time independent (up to 1000 hr.) at temperatures below 800° F. whereas the other alloys showed characteristic creep behavior between 600 and 800° F.; Inconel "X" and A-286 decreased rapidly in strength with increasing temperature. The other alloys had continuously decreasing rupture strength with increasing temperature. Of these, S.A.E. 4340 and A.I.S.I. 410, representing the low-alloy and martensitic stainless steels, respectively, showed the greater decreases in strength with increasing temperature. Throughout the temperature range considered, Inconel "X" possessed appreciably greater strength than the other alloys tested, with A-286 somewhat lower.

All the alloys tested showed notch sensitivity over the temperature range where creep is well developed. Inconel "X" and A-286 show some notch sensitivity even at temperatures where creep is negligible. Inconel "X" and 17-22A (S) showed somewhat similar behavior in that the notch-strength ratio curves exhibited minima at progressively lower temperatures as the time-to-rupture increased. For Inconel "X" and A-286, a fully notch-ductile condition was not completely obtained at these moderately elevated

(*Continued on page* 132)

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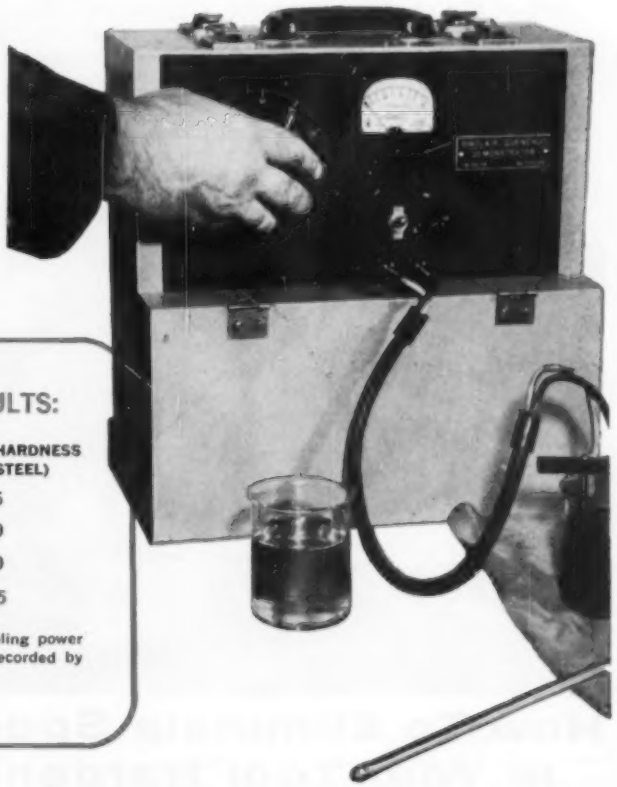

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OILS COMPARED	COOLING POWER*	ROCKWELL C HARDNESS (SAE 1045 STEEL)
Competitive Oil A	576	23.5
Competitive Oil B	729	39.0
Competitive Oil C	1024	41.0
QUENCHOL 521	1369	54.5

*Based on a recognized formula for determining relative cooling power value. Measured as the square of the current (I^2max.) as recorded by Quenchol Demonstrator.

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Stress-Rupture . . .

temperatures. A large notch sensitivity developed in a very short time-to-rupture at temperatures approaching the lower limit of the creep range.

Higher strength levels in the ferritic steels were obtained by increasing the austenitizing temperature and decreasing the tempering temperature. This procedure followed with 17-22 A (S) gave an increase in 1000-hr. rupture strength of about 15% which made it about the same as that of A-286. The change in heat treatment did, however, result in severe notch weakening.

It thus appears that notch sensitivity in ferritic steels is increased in magnitude and shifted to lower temperatures by heat treatments that increase the strength. Similar effects might be expected if the alloy content of hardening elements were increased.

Structural steels, for example S.A.E. 4340, may be heat treated to high strength levels with high rupture strength below 600° F. At higher temperatures, the rupture strength decreases rapidly due to lack of stability. Inconel "X" exhibits the greatest strength and stability (of those tested) between 600 and 1000° F. Alloy A-286 shows similar stability but lower strength over the same temperature range. For temperatures up to 800° F., the modified ferritic steels and 17-4 PH are competitive with A-286. At moderately elevated temperatures, it appears that by increasing the hardness the rupture strength of normalized and tempered ferritic steels can be improved at the expense of increasing the notch sensitivity.

C. O. SMITH

Liquid Metal Corrosion

Digest of "Fundamentals of Liquid Metal Corrosion", by W. D. Manly, *Corrosion*, Vol. 12, July 1956, p. 46-52.

IN ORDER TO DEFINE the destruction of a solid metal by a liquid metal as corrosion, the conventional definition must be broadened to allow for the solubility of a solid metal in a liquid metal wherein no transfer of electrons is involved. Liquid metal corrosion depends chiefly upon the solution rate and the extent of solubility of the solid metal in the liquid metal. However, many complicating factors can influence the solution rate or the attainment of a solubility limit. The formation at the alloy surface of intermetallic compounds and oxide or nitride films are good examples of such factors. In addition, impurities in the liquid metals frequently increase the solution rate. Still other factors are temperature gradient, and multimetallic systems which can cause increased attack because of mass transfer of material under the driving forces of the temperature gradient or concentration gradient.

In this paper the following types of liquid metal attack are discussed:

1. Simple solution.
2. Alloying between liquid metal and solid metal.
3. Intergranular penetration.
4. Impurity reactions.
5. Temperature gradient mass transfer.
6. Concentration in gradient mass transfer, or dissimilar mass transfer.

In the discussion of forms of liquid metal corrosion, the simple solution-type attack is described as uniform removal of metal from the surface to saturate the liquid metal. From available equilibrium diagrams of liquid metal-solid systems, one can ascertain and predict the extent of attack that will occur as a result of

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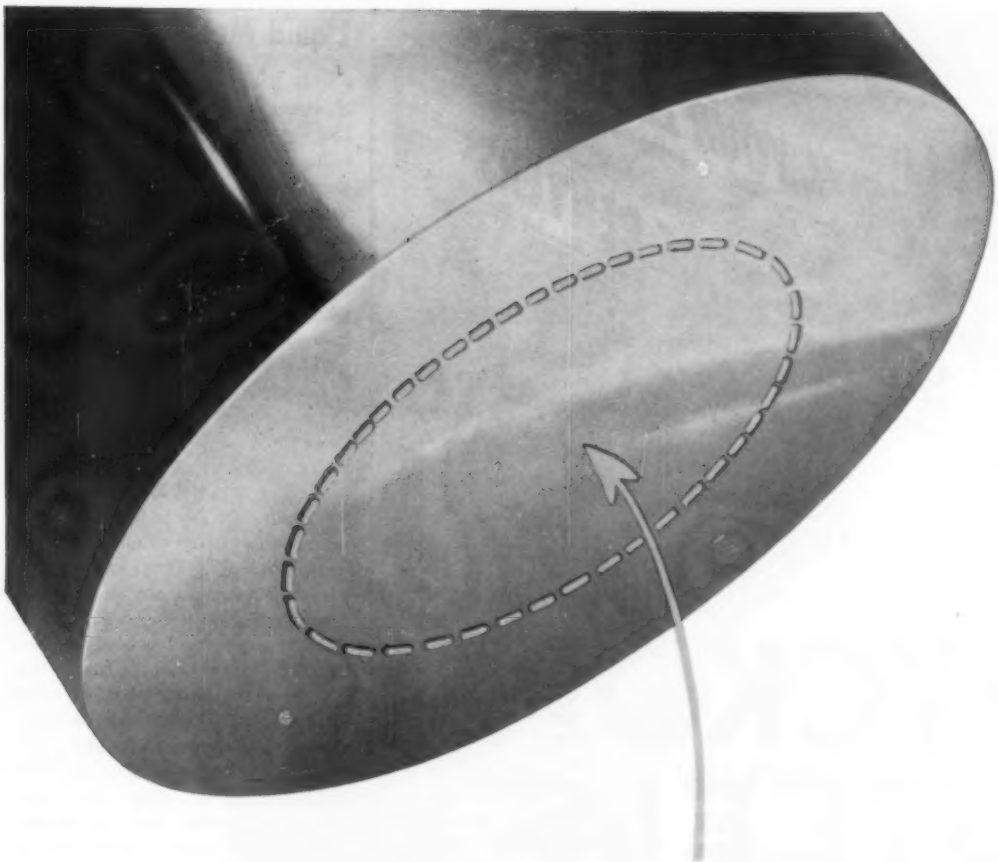

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Liquid Metal . . .

simple solution in a static system. However, such information gives no bearing on the rate at which the solubility limit is achieved. Thus, in simple solution attack, the ultimate amount of damage the solid metal will receive depends on the ratio of metallic surface area to liquid volume of the systems, but the rate at which the attack occurs can be influenced greatly by other variables such as impurities in the system.

For alloying action to occur between liquid metals and solid metals, there must be some solubility of the liquid metal and the solid metal. In some cases, the liquid metal dissolves considerably in the solid metal with the formation of an intermetallic compound. Thus sodium will penetrate solid copper at the grain boundaries and will form an intermetallic compound which is considerably harder than the base metal.

Another of the more serious types of liquid metal corrosion is intergranular penetration brought about by the selective removal of one constituent from an alloy. In liquid metals, impurities such as oxygen, nitrogen, and carbon often have a very significant effect upon the rate of attack. In some cases, the whole mode of attack can be changed because of the effect of impurities on surface tension or because of the reactivity of the impurity.

The most damaging type of liquid metal corrosion is temperature gradient mass transfer. The uniform removal of a slight amount of a container wall will not adversely affect its load carrying abilities; however, the collection of this material in the colder regions of heat exchanger tubes as dendritic crystals may eventually cause plugging and cessation of flow. When there is a selective removal of one element from an alloy, atoms of the element removed must diffuse to the surface and then pass into solution. These atoms must then diffuse through the lamellar layer into the liquid stream and finally be carried to the cold portion of the systems where supersaturation will occur. A collection of such atoms will form a nucleus that will grow to stable size and then separate from the liquid. On the other hand, the atoms may supersaturate close to the wall, diffuse

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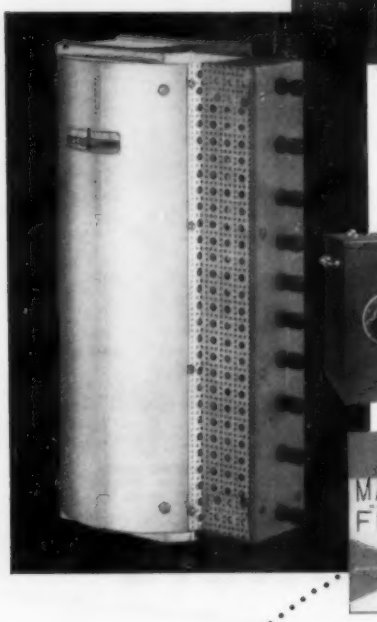

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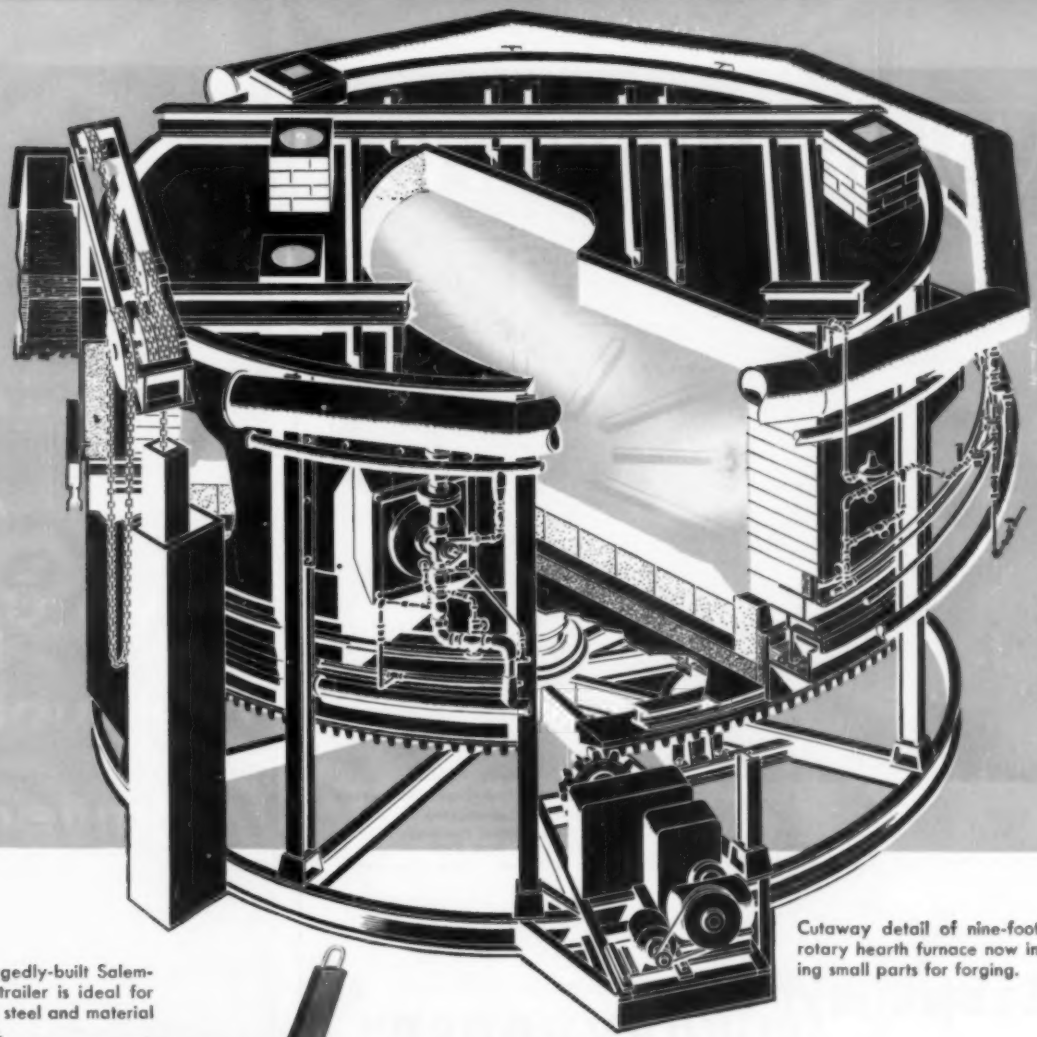
Liquid Metal . . .

through the lamellar layer, and then nucleate on the metallic wall and form dendritic crystals or diffuse into the wall. As yet the exact nature of the rate-controlling steps in temperature gradient mass transfer have not been fully determined.

Another form of mass transfer is termed dissimilar metal mass transfer or concentration gradient mass transfer. A schematic concept of the manner in which this type of attack takes place may be described as follows: Metal A and Metal B are in simultaneous contact with liquid metal. Atoms of Metal A go into solution and move to the surface of Metal B either by diffusion or by movement of the liquid. When these atoms of A reach the surface of metal B they come out of solution, alloy with metal B, and diffuse inward. The driving force for dissimilar metal transfer is the decrease in free energy achieved through the alloying of the two metals. The larger the difference between the chemical potentials of A and B in the two solid phases, the greater will be the driving force for the occurrence of mass transfer.

A number of variables or rate factors affecting liquid metal corrosion are also discussed. Temperature, for example, is one of the most important variables because the higher the temperature, the higher the solubility of the solid metal in the liquid metal. Furthermore, when a temperature gradient exists in a liquid metal system, the difference in solubility of the dissolved metal in the liquid metal between the hot and cold parts of the system gives rise to temperature gradient mass transfer. Cyclic temperature fluctuations are sometimes helpful in explaining apparently erroneous static corrosion results. For example, under supposedly isothermal conditions in a poorly controlled furnace, the liquid metal-solid metal interface temperature can fluctuate quite appreciably around the mean temperature, thus setting up small but definite temperature gradients with resultant mass transfer effects.

The ratio of surface area of solid metal to the volume of liquid metal is frequently a controlling factor in the amount of corrosion experienced in a liquid metal system. This is



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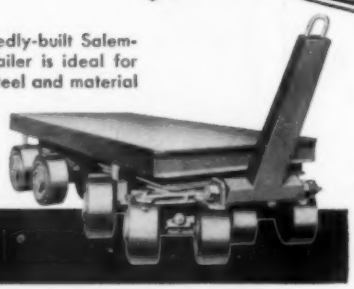

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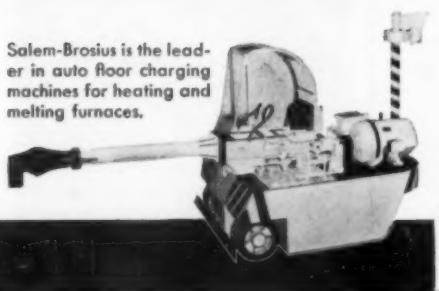

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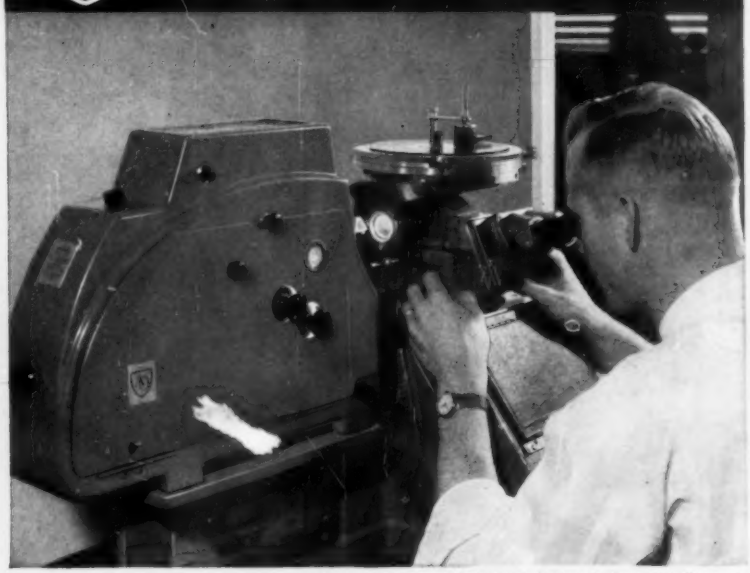

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Liquid Metal . . .

true since the metal will corrode sufficiently to saturate liquid metal at the operating temperature. Thus as the ratio of surface area to volume decreases the amount of corrosion increases. In many cases, purity of the liquid metal can have a quite substantial effect on the rate at which the solubility limit is reached and can also markedly affect the wetting tendency of the liquid metal on the solid metal. The remaining factors, dealing with flow velocity, and condition of the container materials are less critical in controlling corrosion effects but each must be understood and considered.

For successful containment of liquid metals, the amount of impurities such as oxygen, nitrogen, and carbon must be carefully controlled. Further work in the field of liquid metal corrosion must be directed toward increasing the understanding of the rate-controlling steps of dissimilar metal mass transfer and temperature gradient mass transfer. When these have been accomplished, corrective measures can be taken to keep these types of corrosion to a minimum. W. W. AUSTIN

Gas Turbine Blades for 2200° F. Service

Digest of "The Development of Refractory Nozzle Blades for Use in High-Temperature Gas Turbines", by T. H. Blakeley and R. F. Darling, presented before the North-East Coast Institution of Engineers and Shipbuilders (Great Britain), Feb. 8, 1957; Digested in *The Engineer*, Vol. 203, Feb. 15, 1957, p. 251-252.

THIS PAPER is a summary of previous papers published by the same authors in *The Engineer* in August and October 1955, and July 1956. The main problem under discussion is the development of materials for gas turbine nozzle blades operating at 2200° F. and higher. The authors assume that in such a high-temperature turbine the rotating blades will be cooled and only the nozzle vanes would have to withstand the temperature. An experimental single-stage turbine operating at 2200° F. was designed, the nozzle vanes being supported at both ends to reduce stresses and simplify the mounting.

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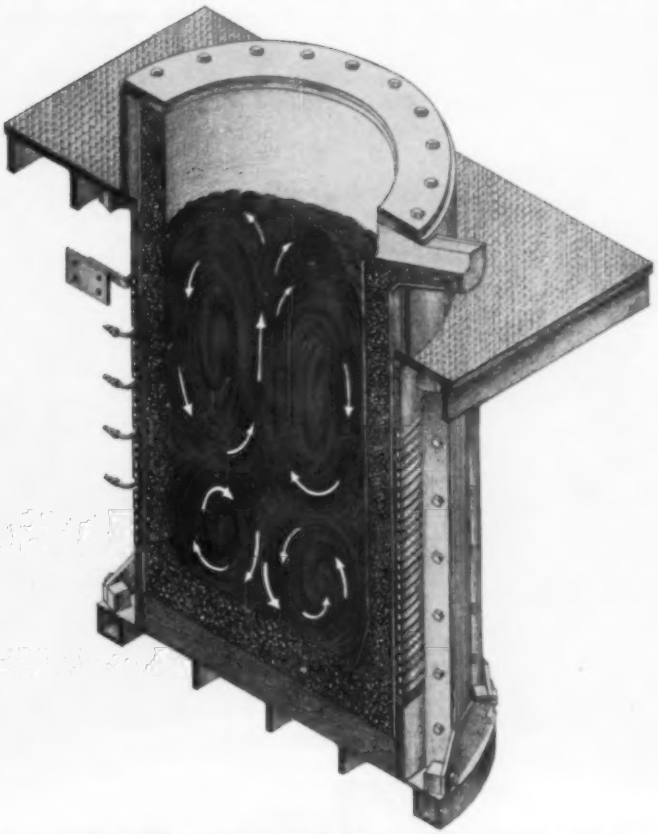

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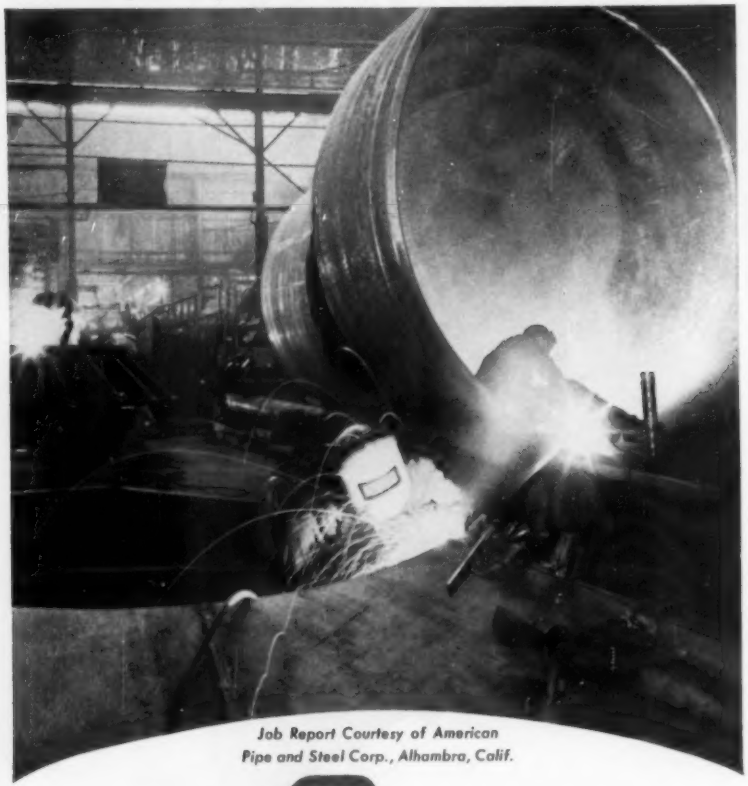

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Turbine Blades . . .

The most drastic thermal shock conditions were achieved by reducing the gas temperature abruptly from 2200 to 1000° F. The resistance of aluminum blades to thermal shock was unsatisfactory. Zircon-chrome blades resisted 10 to 12 thermal shocks. Under steady state conditions at 2200° F., yielding and creep took place after 80 to 150 hr. of service; eventually the blades ruptured. Blades composed of 75% chromium, 25% aluminum oxide alloy had excellent thermal shock properties but had insufficient strength at high temperature to prevent excessive creep. Finally a self-bonded silicon carbide body was developed; blades made of this material gave excellent results in both thermal shock and high-temperature creep tests. After a total running time of 363 hr. at 2200° F., the blades showed very little damage. Although the final tests in an actual turbine were not completed at the time the paper was written, the authors feel confident that a satisfactory silicon carbide material can be developed for stator blades operating at 2200° F.

POL DUWEZ

Influence of Understressing on Fatigue

Digest of "The Influence of Understressing on the Fatigue Properties of Flake Graphite and Nodular Graphite Cast Irons", by G. N. J. Gilbert and K. B. Palmer, *Journal of Research & Development*, British Cast Iron Research Assoc., Vol. 6, December 1956, p. 410-421.

A FATIGUE TEST specimen subjected to cycles of stress at or below the fatigue limit is considered to be understressed by definition of the term. Some investigators hold the view that understressing will strengthen a metal or alloy and raise its fatigue limit, the amount depending upon the material under test. The method of finding the effect of understressing on fatigue properties most widely used involves increasing the level by a series of small increments until fracture occurs.

Some time ago an understressing test was carried out at the British

Cast Iron Research Assoc. on a flake graphite cast iron. The original fatigue limit was not found to change after understressing at the fatigue limit for 20,000,000 cycles. This information was not published since it appeared to contradict the results of other workers. A series of tests on pearlitic and ferritic flake and nodular cast irons was therefore planned, and the current report gives the results.

The ferritizing heat treatment used for the flake and nodular irons was 8 hr. at 900° C. (1650° F.), followed by furnace cooling to 690° C. (1270° F.) where the batch was held for 24 hr. prior to furnace cooling to room temperature.

The fatigue tests were carried out on Woehler-type machines built at the institute using standard dimensions for the specimens.

It was found that the pearlitic flake graphite material had an unusually high tensile strength for an unalloyed iron to begin with and therefore exhibited a correspondingly high fatigue strength. After understressing, no significant effect on the fatigue properties of the pearlitic and ferritic flake and nodular irons tested could be noted. Likewise, the shapes of the fatigue curves were not appreciably altered. In other words, not only did the fatigue limit remain constant after understressing but the fatigue life at stresses over the fatigue limit was unaffected.

Other investigators have previously reported increases in fatigue limit in excess of 30% due to understressing, and in view of this the results obtained at the British Cast Iron Research Assoc. are rather surprising. HANS HEINE

Refractory Oxide Coatings

Digest of "Characteristics of Refractory Oxide Coatings Produced by Flame Spraying", by Neil N. Ault, *Journal* of the American Ceramic Society, Vol. 40, March 1, 1957, p. 69-74.

BECAUSE of their high melting points, refractory oxides cannot be fused on the metal in a furnace. The technique used consists of introducing the oxide into a high-temperature flame, melting it and projecting the molten droplets on

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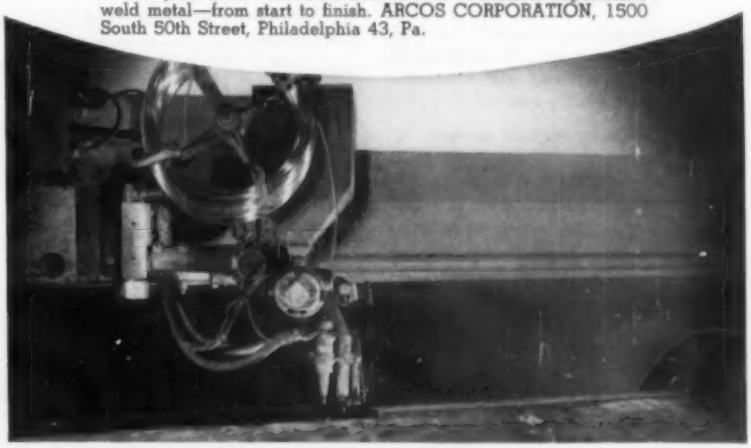

Oxide Coatings . . .

the surface of the metal to be coated. The refractory oxide can be introduced as a powder or in the form of a solid rod. The author used the solid rod technique. A cylindrical rod about ⅛ in. in diameter is fed into an especially designed torch (acetylene-oxygen) at a rate of about 5 to 10 in. per min. As the rod melts, compressed air at a pressure of 80 psi. projects the molten particles on the metallic surface. This method is not applicable to all ceramic compounds. According to the author, a limiting factor in determining the suitability of a compound is that it should melt in the flame and must not volatilize. The reviewer believes that a still more important factor is the chemical reactivity of the compound with the high-temperature flame. An acetylene-oxygen flame is generally highly oxidizing and if compressed air is used for projecting the liquid particles onto the metal surface, the chances for oxidation are still greater. It is therefore not surprising to read in the paper that silicon carbide cannot be successfully sprayed. In addition to the dissociation of silicon carbide at high temperature, its reaction with oxygen cannot be overlooked. It is quite obvious that a compound which does not dissociate at high temperature but reacts with oxygen cannot be successfully sprayed by the technique described by the author.

Three of the most important coatings for practical applications are discussed at length, namely aluminum oxide, zirconium oxide and zirconium silicate. When aluminum oxide is sprayed on a metallic surface, the structure of the coating is that of gamma alumina. A coating approximately 0.017 in. thick has a bulk density of 3.38 to 3.35 and hence the total porosity is between 9.7 and 7.6%. The structure of the coating is laminar, because it is built up of flattened droplets of molten alumina. The thermal conductivity of the coatings decreases with increasing temperature from about 0.012 to 0.007 cal./sec./°C./cm.^{3} between 175 and 1050° C. (350 and 1920° F.). The mechanical properties of the coating could not be measured on the coating itself which is too thin for this purpose. Thick coatings were prepared on graphite as a substrate and the modulus of rupture measured on bars 3½ in. long and ½ in. wide was between 3700 and 5500 psi.

In coatings made of zirconium oxide, rods of lime-stabilized zirconia were used in the torch. Zirconia coatings are laminar, but the laminations are not as well defined as in the case of alumina. The bulk density is about 5.2, and the total porosity is 8.9%. Although the calcium oxide content of the zirconia was not sufficient to stabilize the oxide into the cubic form, the structure of the coating was found to be 100% cubic zirconia. After reheating the coating, however, a fraction of zirconia reverted to the monoclinic form, as shown very clearly by the thermal expansion measurements described by the author. No thermal conductivity nor strength data are given for the zirconia coatings.

Coatings made of zirconium silicate (zircon) present less lamination than either alumina or zirconia coatings. The structure of the coating is glassy and X-ray diffraction patterns were very diffused; the author interpreted these patterns as a proof of the presence of cubic zirconia. The fact that zirconium silicate decomposes before melting is in agreement with the accepted ZrO_2-SiO_2 phase diagram. It is surprising, however, to find the cubic

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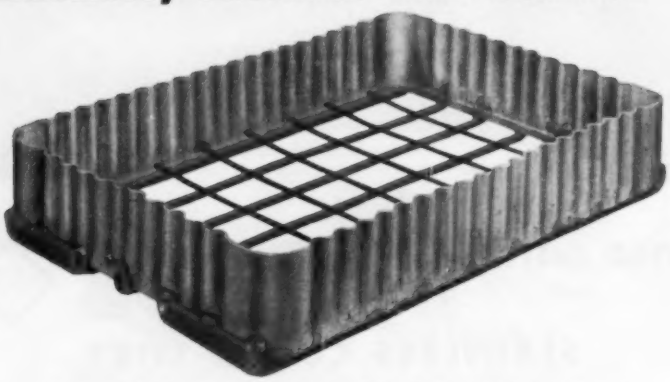

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316	431A	5358	5389	5735	30347	60410
321	436	5360	5392	5765	51410	60420
327	440A	5361	5393	6270F	51414	60442
329	440B	5362	5394	6274F	51416F	60446
330	440C	5363	5526	6280C	51420	70310
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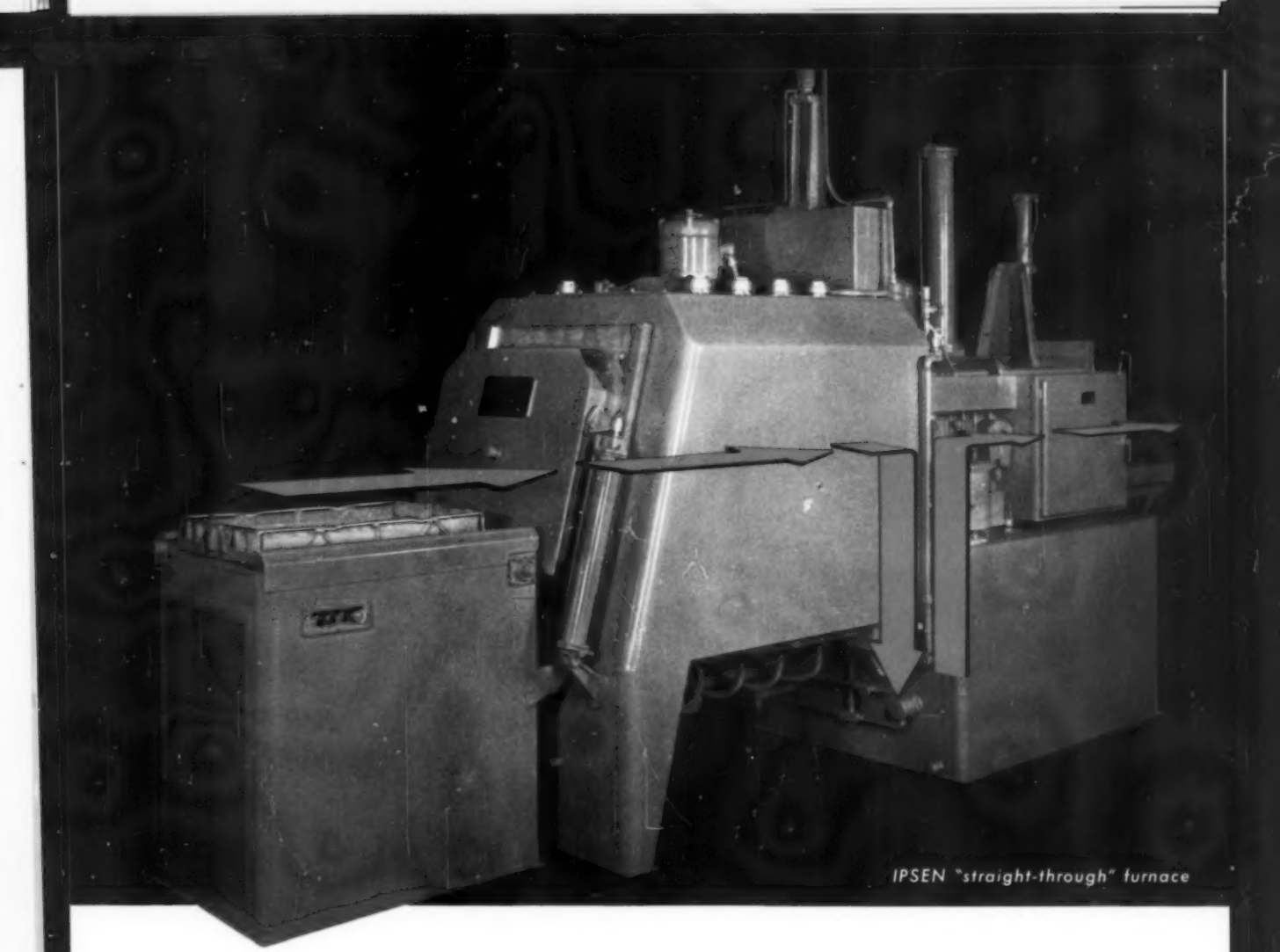

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following page shows floor plans for both job lot or continuous installations

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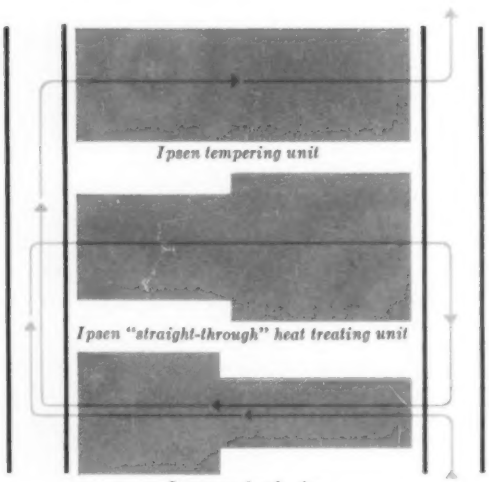

This arrangement includes an Ipsen Washer unit, an automatic "straight-through" heat treating unit, and a tempering unit installed side by side. Two transfer cars operate on crosstracks which connect the three units at both the charge and discharge ends.

Loaded work tray enters the washer . . . emerges from the discharge end to the transfer car which moves the tray to the charging end of the heat treating unit. Tray then enters the work chamber of the heat treating unit . . . passes from the discharge end to the transfer car, then back to and through the washer. The next transfer is into the tempering unit, and the work is ready for the next step of manufacture.

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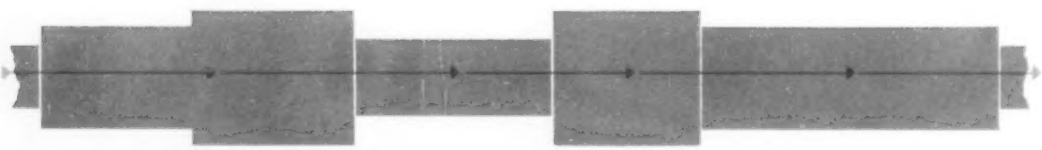

This is a completely automated installation. Special Ipsen-designed mechanisms receive the loaded work trays, move them into the furnace work chamber . . . later transfer them from the discharge end of the heat treating unit to a washer . . . then from the washer to the tempering unit . . . and finally out of the tempering unit to the next processing point.

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Oxide Coatings . . .

form of zirconia instead of the monoclinic form in the coating.

The bulk density of the coating is about 3.79, with a total porosity of 8.8%. There are relatively more closed pores in the zircon coatings than in both the alumina and zirconia coatings, and this is in agreement with the glassy nature of the coating which is the result of the presence of silica glass. After reheating the coatings to about 1500° C. (2730° F.) while making thermal expansion tests, the structure reverted to the monoclinic form of zirconia, as shown by a very drastic change in length during cooling. The presence of monoclinic zirconia was confirmed by X-ray diffraction measurements made on the specimens used for the thermal expansion tests.

POL DUWEZ

Chevron Patterns in Steel Fractures

Digest of "The Study of Fracture Surface Markings", by C. F. Tipper, *Journal* of the Iron and Steel Institute, Vol. 185, January 1957, p. 4-9.

THE FRACTURE surfaces of brittle failures in structural mild steel always contain some degree of the so-called "chevron pattern", with this pattern having some resemblance to that appearing on the fracture surfaces of crystals, glass and plastics. The explanation of many of these markings is based on the assumption that separate fractures, initiated at several points, unite to give complete fracture. There is also evidence that, in materials which undergo some plastic deformation both before and during fracture, fracture is a discontinuous process. In mild steel at low temperatures, cleavage fracture is always associated with some plastic deformation and with normal fracture of some crystals.

Dr. Tipper has developed a rational explanation of the relationship between plastic deformation and crystal fracture and of the formation of the chevron pattern.

His evidence supports the theory of the discontinuous process in fracture propagation. The processes involved in fracture propagation are the same, ranging from the smallest cracks to large-scale over-running cracks, and including service fractures where overlapping fractures are often found. If the cracks are end-to-end, they can unite by the simple process of extending into each other. In all other cases, however, they must join through breakdown of the material separating them, either by secondary cleavage in the case of single crystals or by shear. The usual mode of breakdown is shear failure of the "bridges" between cracks. A process of this type inevitably leaves a step, and these steps cause the markings observed on the cleavage faces of crystals and the striations and chevrons observed in polycrystalline metals and plastics.

It is expected that the mean path of fracture would be perpendicular to the principal tensile stress and that deviating secondary fractures would be arrested in ductile material. Branching of fractures in glass and plastic is characteristic of high-velocity propagation, but an opposite behavior occurs where branching leads to a greater amount of plastic deformation, as with ductile metals.

Fracture progresses and produces the observed structures as follows: There is a maximum tendency for fracture to continue into the metal and form undersurface cracks in the direction in which the fracture is moving. In addition, some cracks have been observed at the base of sharp discontinuities facing away from the fracture origin, but these are limited in extent so that fractures have a directional character. Centers of possible new fracture origins probably occur at positions of maximum tensile stress with fracture spreading in both directions. These local failures are inclined with respect to the mean path of fracture with further failure by shear between these local failures to give complete fracture along the mean path.

Arrested fractures generally show that the center of a plate fractures before the surfaces with the extent of advance depending on the relative velocity of propagation in the two directions of the plate. Laminations and certain nonmetallic inclusions constitute barriers to fracture propagation and thereby influence the fracture and the markings.

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Investigation of Corroded Parts

Digest of "Application of a Systematic Scheme for Examining Corroded Metal Specimens", by J. B. Cotton and R. J. Watkins, *Corrosion Technology*, Vol. 4, February 1957, p. 39-43, 74.

A SYSTEMATIC METHOD for the examination of corroded metal specimens by the use of standard techniques such as visual examination, X-ray diffraction, chemical, spectrographic and microchemical analysis, measurement of potential differences, and electron diffraction has been developed. The following histories are presented as examples.

A copper hot-water storage cylinder operating in a hard-water area had become perforated on the top dome in zones near the seam. Specimens of the parts were obtained for chemical and spectrographic analysis, and samples of the various corrosion products were subjected to microchemical analysis. All the parts were found to meet specifications. The corrosion products were found to consist of basic copper carbonate, iron rust, chloride and sulphate ions, zinc, silica, sodium and borate ions. A vitreous film was also found beneath the corrosion products; X-ray diffraction methods identified it as cuprous oxide.

These findings led to the conclusion that the brazing flux had not been washed off. Since the flux was corrosive, it had probably exposed the bare copper by removing the protective film. Galvanic corrosion then occurred because of the potential difference between the copper and the vitreous cuprous oxide. This theory was substantiated by electrode potential tests with a calomel electrode. Metallurgical examination also revealed two secondary corrosive effects: (*a*) dezincification of the brass bosses, and (*b*) galvanic corrosion between the brazing alloy and the copper.

A plug cock used in the gage of a boiler carrying high-alkali water had failed in service. Chemical and metallurgical examination revealed that it was made of a wrought leaded aluminum bronze and that it was free from manufacturing defects. The cock had a typical duplex microstructure consisting primarily of alpha-beta with a semicontinuous network of alpha-delta. Preferential corrosion of the alpha-delta phase had taken place. Under certain circumstances this type of bronze is susceptible to attack by caustic soda solutions. The alkaline boiler water had seeped down between the plug and the packing sleeve, and had become highly concentrated. The concentrated solution resulted in local crevice attack causing failure.

A wire mesh screen made of 18-8 stainless steel with 2% Mo failed in service in a unit used for concentrating methylene dichloride liquors. The screens were mounted on stainless steel brackets in a drum of the same material, and beds of activated charcoal were placed on them. The methylene dichloride was passed over the beds to be absorbed by the charcoal. At the saturation point, steam was blown through the unit to remove the concentrated chlorides. Only the wire mesh corroded; the brackets and drum were not affected. Chemical and spectrographic analysis revealed that the material met the specifications. Microchemical analysis and X-ray techniques identified the deposits found in the failed areas as magnetic iron oxide and aluminum silicate. In addition, visual examination revealed that the failure had started on the side in contact with the charcoal after pitting had occurred. This type of stainless steel is known to be sus-

(*Continued on page* 148)

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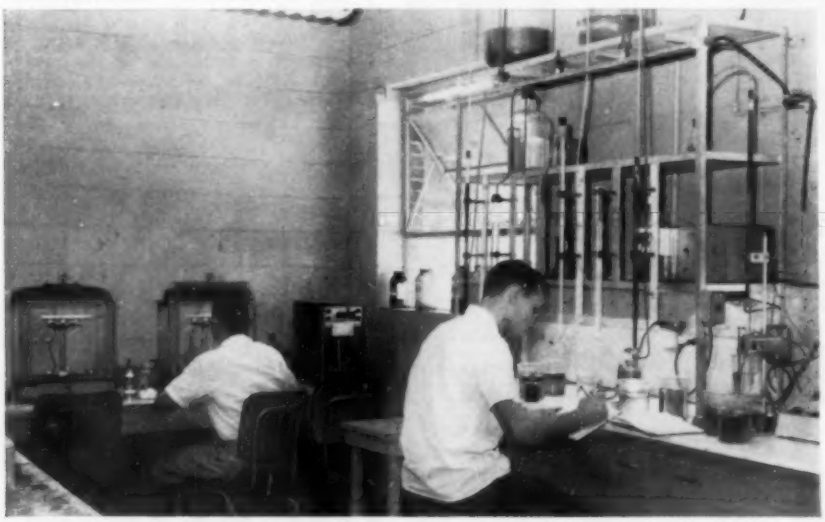

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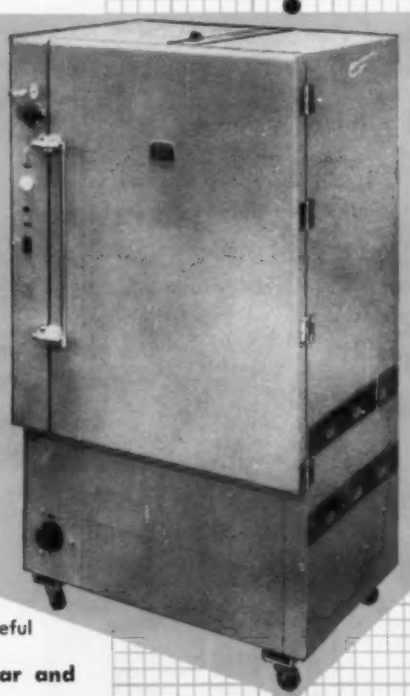

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Corroded Parts . . .

ceptible to pitting attack in the presence of chlorides. Therefore, it was deduced that the failure was caused by the dichlorides being hydrolized to chlorides; this resulted in pitting. The reaction was accelerated by the presence of carbon which acted cathodically to the metal. BERNARD TROCK

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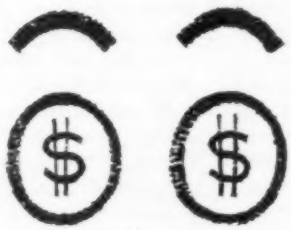
Effect of Impurities on Oxidation Mechanism

Digest of "Role of Minor Elements in Oxidation of Metals", by Earl A. Gulbransen, *Corrosion*, Vol. 12, December 1956, p. 61-67.

IN ELEVATED-temperature oxidation of metals, impurities have a major effect on the oxidation mechanism. The present investigation is an effort to further the understanding of the role of impurities and minor elements in oxidation. Each of the various impurity effects is classified in terms of its influence on the physical and chemical structure of the oxide formed.

At least two conditions must be met if the impurity atom is to form its own oxide in the outer layer. Since the activity of the impurity atom in the metal is low, its oxide must be much more stable thermodynamically than the oxides of the main components. In addition, the impurity atoms must have high mobility.

Whenever certain bivalent oxides such as NiO and CoO are reacted with trivalent oxides such as Cr_2O_3 and Fe_2O_3, a spinel is formed. These spinels are stable thermodynamically,



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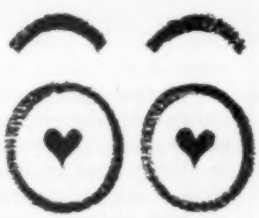

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Oxidation . . .

and many minerals and oxides possess such structures. The substitution of foreign metal atoms in the spinel structure can occur without a large change in lattice parameters. In view of the flexibility and stability of these spinel structures, it is suggested that the oxidation resistance of heat resisting steels is due to the formation at the oxidized surface of a stable spinel.

In the event that one or more of the minor components of the oxide film diffuses with great difficulty for reasons such as size, charge, or solubility, segregation of these oxides may occur in contact with the alloy interface. If sufficiently impervious, these films could control the rate of reaction. Thus, if the oxide film prevents metal ions from moving into the outer layer, the reaction would be effectively stopped. Although the possibility for such a phenomenon exists, no proven example has been observed.

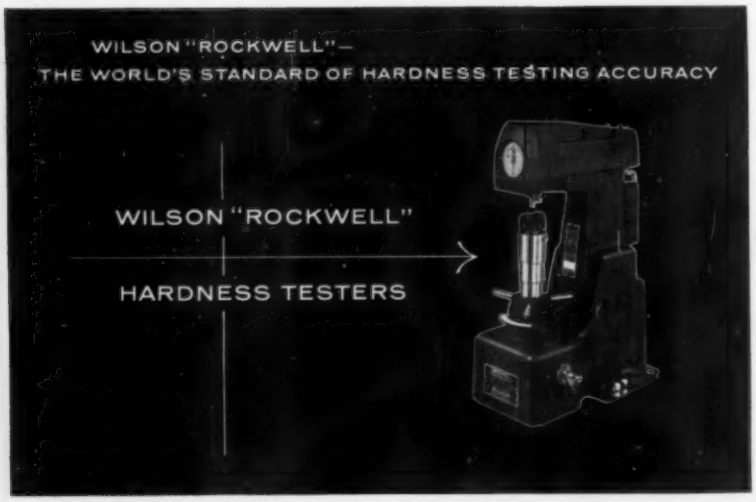
Previous workers have considered the influence of additions of metallic impurities on the conductivity and the rate of oxidation. Thus, if one accepts the Wagner theory of oxidation, and also assumes that mobility of the disordered ions and electrons is not changed by the presence of foreign ions, then it is necessary to diminish the number of ionic defects in order to increase the rate of oxidation. This is best understood by the application of the law of mass action to ionic and electronic defects in mixed crystals.

In considering changes in physical properties and adhesive properties of oxide and oxide-alloy interfaces, it is emphasized that minor components may concentrate in the surface layer of the alloy forming silicate films, thus changing the physical properties of the oxide-alloy interface. Hence, if minor components tend to embrittle the oxide, stresses set up between the oxide and the metal may cause cracks within the oxide rather than between the oxide and the alloy. If the concentration of minor components or their oxides tends to weaken the bonding between the oxide and the metal, the oxide may scale in large sections. In addition to such physical considerations, the concentration of minor components as oxides or as elements at the oxide-alloy interface may alter the reactivity of the grain boundary between alloy crystals.

The effect of strain on the rate of oxidation was studied recently using a sensitive weight gain method, since the effect of the strain can be evaluated at an early stage by observing the rate of oxidation before and after application of stress.

Experiments were made to determine the effect of silicon on the adhesion of the oxide to the metal for the nickel-chromium series of heater alloys. Strain was applied to the system of metal-plus-oxide after a certain initial oxidation occurred. Silicon increased the rate of oxidation at constant temperature; however, when the system was placed under strain, silicon improved the over-all oxidation resistance. These experiments suggest that impurity elements such as silicon in the metal or alloy can affect greatly certain physical and chemical properties of the oxide and oxide-metal interface. These results show a direct correlation with the A.S.T.M. useful life tests on heater alloys.

Results indicate that the oxidation of well-annealed polished samples of iron occurs in a discontinuous manner at high temperatures and at low oxygen pressures. Well-oriented oxide nuclei form at apparently random positions in the metal grain.



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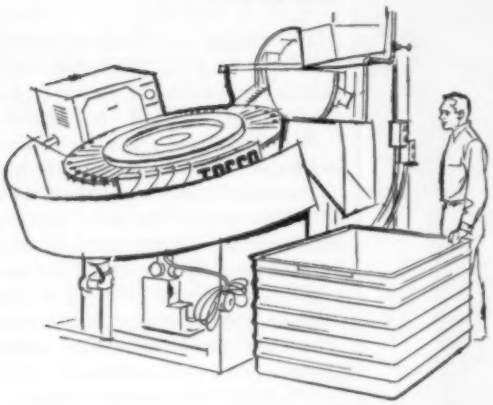

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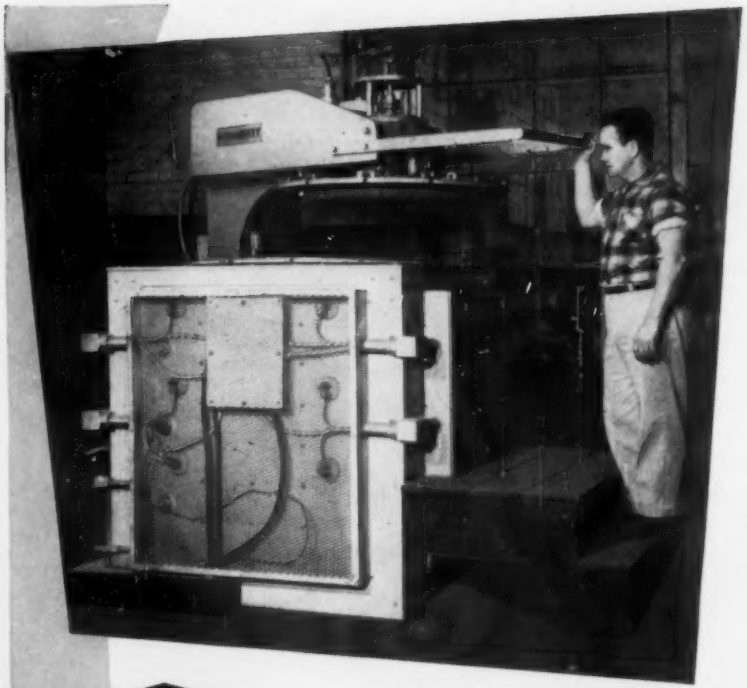

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Oxidation . . .

The condition and extent of oxidation are carefully controlled and measured, and electron optical methods are used to study the finer details.

A careful analysis of experimental results in this investigation has led to several interesting conclusions about the role of the metal and its inclusions and defects on the process of nucleation and growth of oxides:

1. Single crystals of oxides do not form on a single grain of the metal. The occurrence of many oxide growth centers on each grain may be related to the presence of defects and inclusions in the metal grain.

2. Occurrences of circular growth patterns in oxides probably are related to inclusions.

3. The density of oxide growth centers is of the same order as the density of dislocations in the metal. An interrelation is postulated.

4. The grain-boundary area of a metal presents an interface where impurity atoms may concentrate. Thus the grain-boundary area may present a lower activation energy for oxidation than other areas in the crystal. The magnitude of this difference in activation energies is determined in part by the difference in orientation between the two adjacent grains. WM. W. AUSTIN

Sintered Steel From Darkest Africa

Digest of "The Matakam Story — From Prehistoric Iron to Modern Sintered Steel", *Powder Metallurgy*, Vol. 8, June 1957, p. 4-16.

THE FACT that sintered steel suitable for sickles and axes is being made by a tribe in darkest Africa is another reminder that "there is nothing new under the sun". The Matakam tribe live in the Mandara mountains in French Cameroon in West Africa. Matakam smiths pulverize iron sponge obtained by smelting ore, sort out the impurities, and place the ductile flakes, platelets and other iron particles in a sintering crucible. They produce over a charcoal fire a sintered product which is forged and resintered.

The result is a material consisting of pure ferrite and pearlite regions

with from 0.4 to 0.6% carbon. Examination of a section of ingot showed practically no manganese, silicon, phosphorus, or sulphur with 0.4% carbon.

During the dry season, the magnetite is washed out of the alluvial deposits and brooks where the oxide has been concentrated during the rains. The washed ore, which is to a large extent freed from gangue, is stored in containers. The charcoal is mostly produced directly in a reduction furnace, broken to nut-sized pieces and stored in a pit next to the furnace.

The Matakam have a double bellows at the top of the furnace and a clay pipe connected with the bellows leading almost to the bottom of the furnace. To start a run, the furnace is charged with charcoal to more than half its height whereupon the large oval furnace door is sealed with clay. After the fire is started and the furnace brought to temperature, a slag notch is broken out, near the bottom of the furnace. At intervals of about a quarter of an hour, a few handfuls of ore and a cup of charcoal are charged through the round opening at the top. A FeO-rich slag (60% FeO and 35% SiO_2) flows out of the slag notch.

After a certain time of reduction, the notch is sealed with clay, and a new notch is broken out at a slightly higher position. At the end of the run, which may last up to 24 hr. at 2000 to 2100° F., the furnace is opened, the sponge iron cake is withdrawn and quenched in water.

This spongy cake is broken down to nut-sized pieces and thereby freed to some extent from chaircoal as well as slag and quartz residues. The coarse pieces are further pulverized by hammering with stone tools, permitting a further purification and separation of the ductile iron grains and flakes. The coarse powder is placed in clay crucibles and densified by shaking. These crucibles are sealed with clay, and the iron is sintered over a charcoal fire with exclusion of air. The sintering crucibles are then broken up, the sintered iron removed and forged in the charcoal fire with large, rounded two-handled stone hammers. Repeated annealing and forging produces bars which are finally processed into weapons, jewelry and implements.

H. J. Roast

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Mr. Paul Moffat, manager of manufacturing engineering at the Nuclear Products Division of Metals & Controls Corporation, added that they are exceptionally pleased with the long heating element life under severe operating conditions and the wide variety of uses at temperatures to 1850°F.

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Annealing Furnace for Motor Laminations

Digest of "Annealing Motor Laminations", *Metallurgia*, Vol. 54, December 1956, p. 287-288.

DURING RECENT YEARS the weight-horsepower ratio of fractional horsepower motors has been considerably reduced by use of new materials such as insulating varnishes which permit higher operating temperatures. To insure optimum magnetic properties under these conditions, the stator and rotor laminations must be given a sub-critical annealing treatment. For this purpose the Cambuslang works of Hoover (Electric Motors) Ltd. has installed a Birlec electric radiant-tube furnace of roller-hearth design.

Basically the annealing process consists of heating the steel to approximately 1400° F. to remove all macro and microstrains, and slow cooling so the material is essentially stable and strainfree at room temperature. The rate of cooling does not immediately affect the iron loss but it must be slow enough for complete precipitation of impurities such as carbon, oxygen, and nitrogen since precipitation later on would cause an objectionable increase in the iron loss of the motor. The material must be protected from oxidation until the temperature has dropped to approximately 750° F. in the furnace!

A continuous furnace was selected since the floor space occupied would be much less than for a batch furnace. The furnace is rated at 280 kw. with an output of 1500 lb. per hr. of rotor and stator laminations on a 12-hr. cycle. The furnace is 72½ ft. long including loading and unloading tables and has a usable cross section 4 ft. wide by 1 ft. high. The maximum operating temperature is slightly above that used for the annealing cycle. The furnace rollers are driven by an electric motor through a variable speed gear box, and conventional techniques are utilized for controlling the cycling treatment; these include furnace doors which remain closed when not charging or discharging. Stability of gas atmosphere and economy in gas consumption is thus achieved. The atmosphere is obtained from a Birlec exothermic atmosphere generator having an output of 6000 cu. ft. per hr., operating on commercial gas. An automatically controlled gas-air mixture is burned in a refractory-lined water-cooled combustion chamber, and after cooling and drying the products of combustion are passed through iron oxide to remove hydrogen sulphide.

The furnace is divided into five zones as follows:

Zone 1 – Heating to 1450° F. by electric radiant tubes distributed above and below the hearth. The elements contained in these tubes can be easily changed without removal from the furnace, thus avoiding a complete shutdown should a failure occur. There are 21 tubes operating from a three-phase transformer rated at 167 kva.

Zone 2 – Soaking for 1 hr. Heating elements are the same as in Zone 1. There are 6 tubes and a transformer rated at 48 kva.

(*Continued on page* 158)

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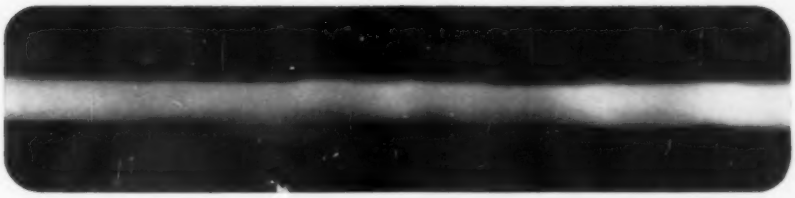

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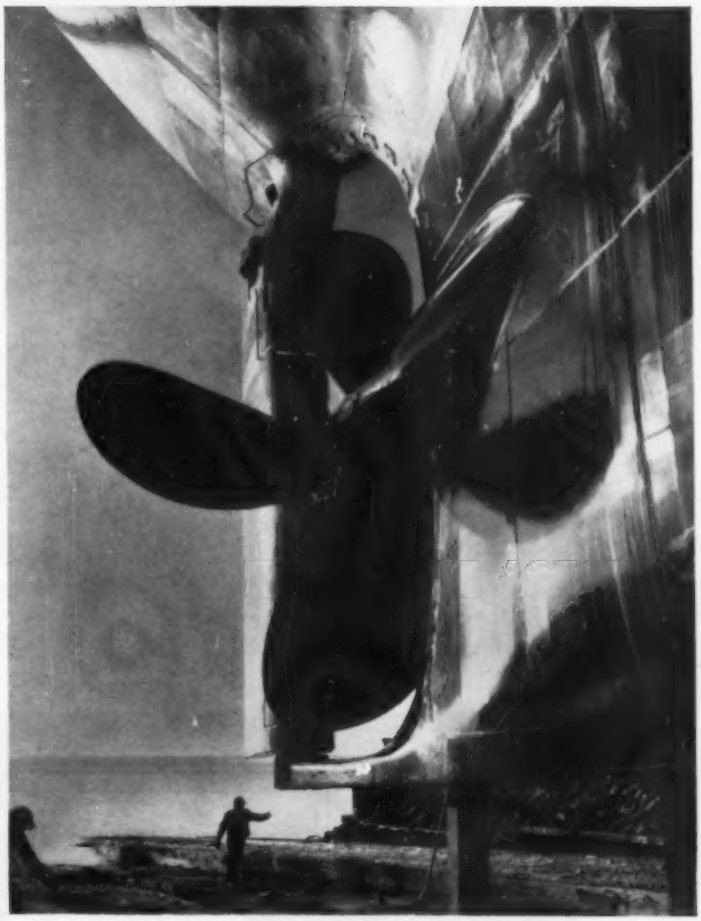

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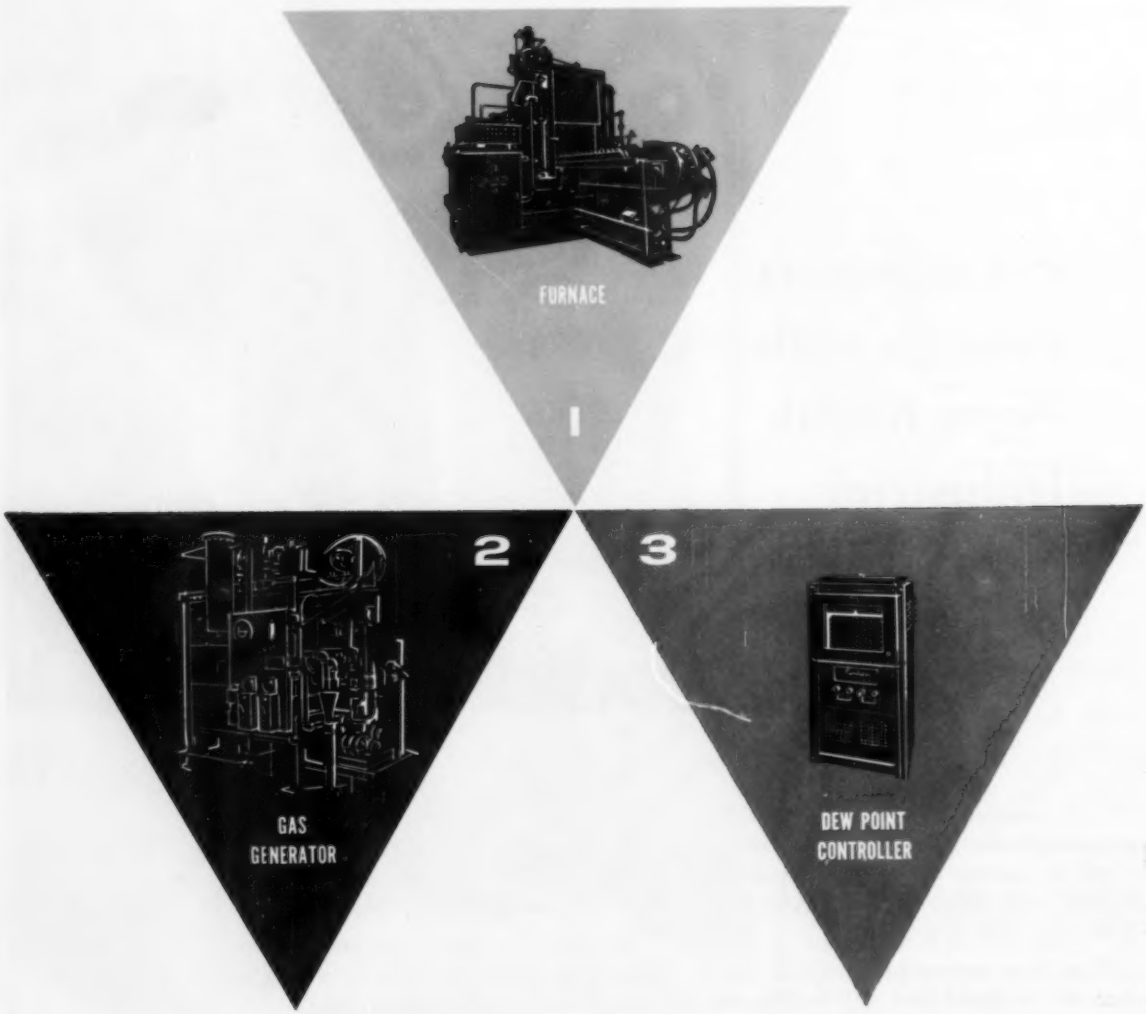
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Role of Strain Rate in Hot Cracking in Castings

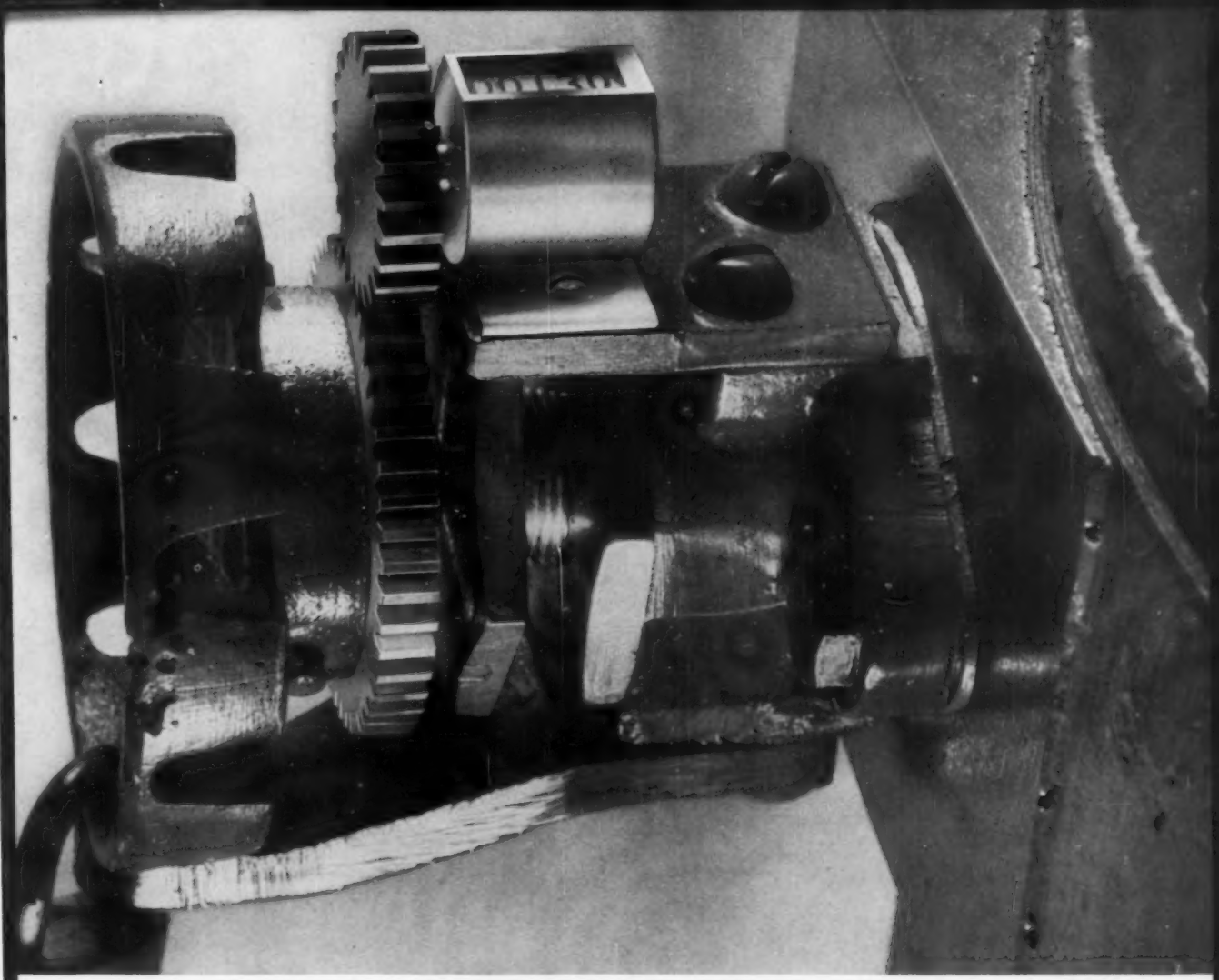
Digest of "Investigation of Metallurgical and Mechanical Effects in the Development of Hot Tearing", by H. F. Bishop, C. G. Ackerlind, W. S. Pellini. American Foundrymen's Society Preprint No. 57-1, 1957, 12 p.

Castings, weldments and forgings may develop intergranular cracks during solidification. This phenomenon, most commonly called hot tearing, is recognized as the most serious defect encountered in steel castings.

Since hot cracking is a phenomenon characterized by failure of the metal to behave in the expected ductile fashion, the basic mechanism should be understood. Two aspects are involved: development of liquid films (metallurgical) and development of strain (mechanical).

The basic elements of the liquid film-strain theory of hot tearing are valid; however, certain foundry alloys hot tear readily while others may be totally immune to this defect.

Three types of tests were conducted on a variety of alloys, classified as the iron, aluminum, and copper-base groups, to determine



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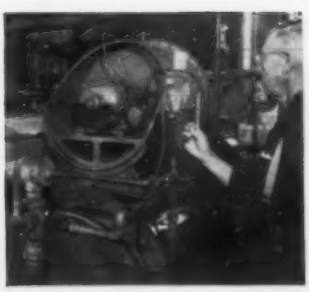

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The Kemp Atmos Generator, a rich exothermic gas producer, is suitable for most furnace applications; while for more critical uses the Kemp Nitrogen Producer is recommended. Both are noted for durability and dependability. Rugged Kemp design gives optimum performance for years, with only minimum maintenance and care.

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Strain Rate . . .

whether correlation exists between hot tearing behavior and metallurgical and mechanical characteristics which lead to hot tearing.

An apparatus was designed for measuring strength of solidifying alloys in such a manner that a test bar fractured under conditions of restraint conducive to hot tearing.

Data obtained indicated that all metals may be expected to develop a sudden transition from zero strength and ductility to high strength and ductility as the liquid film solidifies.

Hot tearing can only occur during the film stage of solidification, which, in the absence of segregate-forming elements, is related to the length of the solidification cycle. A proportion was assumed to exist between film stage time and solidification time; this permitted correlation between film stage life and the amount of contraction occurring during that stage.

It was shown that as the solidification time differential between the hot and cold members of the hot tearing system is increased, the film stage interval and the contraction during this interval are proportionately increased.

Small amounts of impurities may form low-melting eutecties with the base metal, thereby extending the life of the film stage. The FeS-Fe eutectic in iron alloys is a classical example.

Evidence shows that the commercial aluminum, the copper-bearing aluminum alloys, and the plain carbon steels are most sensitive to the presence of segregates which lower the solidification temperatrue, while the nodular and gray irons are affected only to a negligible extent. This agrees with practical experiences which are reported in the literature.

The following factors tend to increase susceptibility to hot tearing of aluminum alloys:

1. Wide freezing range. This prolongs solidification time, delaying acquisition of strength.

2. Low gas content. Casting expansion resulting from gas precipitation counteracts casting contraction, minimizing strains.

3. Large grain size. Fewer grain boundaries cause more concentrated intergranular segregation, which delays acquisition of strength.

4. Low eutectic content. The quantity of continuous liquid films increases with the distance of the composition from the eutectic point.

However, the factor of wide freezing ranges alone is not a sufficient criterion for hot tearing susceptibility and must be considered in combination with the amount of contraction which occurs.

All alloys pass through a critical hot tearing temperature range during the solidification process and can be made to hot tear readily by application of strain at extremely low load levels. In natural mechanical systems entailing the solidification of a casting under conditions of restraint, only certain metals have a tendency toward hot tearing.

HANS HEINE

Stability
must be more than skin deep!
Cincinnati Sub-Zero insures maximum stability of metals . . . even at supersonic speeds!
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New 64 cu. ft. production unit brings 350 lbs. of AM-350 stainless steel per hr. from ambient to minus 120° F.
Speeds of thousands of miles per hour . . . murderous split-second temperature and altitude changes . . . today's aircraft, rockets and missiles survive an almost unbelievable assault in the vital race for preparedness.
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Metal Progress

Bulletin Board...

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Any workman who can tell red from green and count to ten can test the exact strength of pickling solutions . . . *the exact percentage of iron content*, and the solution percentage of sulphuric acid, muriatic acid, alkali etc. in metal cleaning tanks.

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Frank UNIVERSAL
HARDNESS TESTER

It combines tests for Rockwell B and C, Brinell and Vickers in one low-priced machine with NEW push-button load-selector and automatic zeroing for dial gage.

Request Catalog 505

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Portable *and* Precise
HARDNESS TESTER
Model ST-5

- **Weight: 7 oz.**
- **Length: 6¾ in.**

Direct scale readings in Rockwell and Brinell. Make hardness tests anywhere in seconds. Ideal for testing specimens too large for standard testing equipment. Saves time and labor moving heavy pieces to a bench-tester. Quickly calibrated. Easy to read. Used by many large industries. Accessory equipment includes test stand and carrying case.

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THE NEW
DERMITRON
NON-DESTRUCTIVE
COATING THICKNESS TESTER

FAST—ACCURATE
COMPACT—PORTABLE
DIRECT-READING

- *Sorts Metals and Alloys*
- *For Metals on Metals*
- *Non-Conductors on Metals*
- *Metals on Non-Conductors*

You can now have 100% inspection of production of nearly any possible coating on almost any base—including the first and only accurate, direct readings of such combinations as zinc, cadmium, copper on steel; silver on brass; copper on zinc; anodizing on aluminum; organic coatings on non-ferrous metals—without the use of chemicals.

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Inspection Demagnetizing or Sorting PROBLEMS?

SOLVED with

MAGNETIC ANALYSIS MULTI-METHOD EQUIPMENT

Electronic Equipment for non-destructive production inspection of steel bars, wire rod, and tubing for mechanical faults, variations in composition and physical properties. Average inspection speed 120 ft. per minute.

Over 80 installations in steel mills and fabricating plants.

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Electronic Instruments for production sorting both ferrous and non-ferrous materials and parts for variation in composition, structure and thickness of sheet and plating.

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"THE TEST TELLS"

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DL-1001 TENSILE TEST BAR MPA STANDARD 10-51

- Tensile Bars
- Transverse Bars
- Green Strength
- Bushings
- Slugs
- Stepped Parts

Complete design facilities for dies or subpress units to press unusual shapes in lab presses.

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Patent Pending

Accurate test specimens machined from sheet and plate materials .0005 to .500 in., in less than 3 min.

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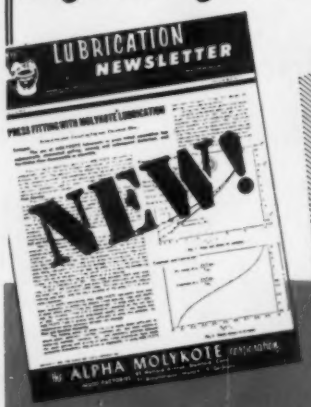
Engineering Data on MOLYKOTE® lubricants



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Pioneer American Standard Since 1907

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OVER 40,000 IN USE

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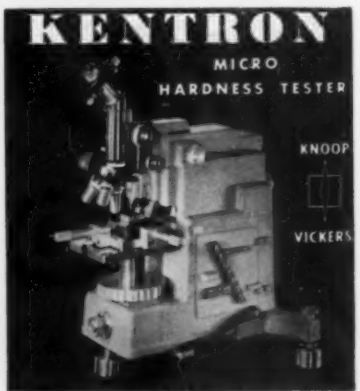
KENTRON

MICRO HARDNESS TESTER



Applies 1 to 10,000 gram loads

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Kent Cliff Laboratories Div.

The Torsion Balance Company

CLIFTON NEW JERSEY

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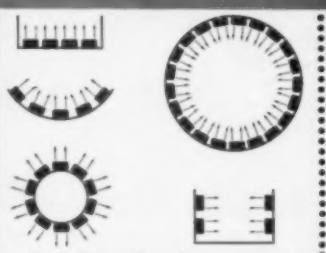
ULTRASONIC CLEANING



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Ultrasonic-Power Generators with hermetically-sealed barium-titanate Transducers — 40Kc/sec.

Transducer Radiating Areas of ¼ sq. ft. to 10 sq. ft. — for use in solvents and detergents.

Eliminates hand operations — Reduces rejects in plating, finishing, assembly.

For washing, degreasing, removal of buffing compounds, radioactive contamination, soldering flux, plaster, carbon smut, etc.

Literature upon request.

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Specializing in Ultrasonics Since 1946

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WELDCO FABRICATED MONEL PICKLING EQUIPMENT

• Hairpin Hooks • Sheet Crates

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• Mechanical Bar, Tube and Coil Picklers

THE YOUNGSTOWN WELDING & ENGINEERING CO.

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CIRCO Since 1923

Specialists in All Phases of METAL CLEANING EQUIPMENT

- DEGREASERS • AGITATING WASHERS • PICKLERS
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We will be happy to send a sales engineer to help you with any metal cleaning equipment problem. Complete information on request.

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CIRCO EQUIPMENT COMPANY

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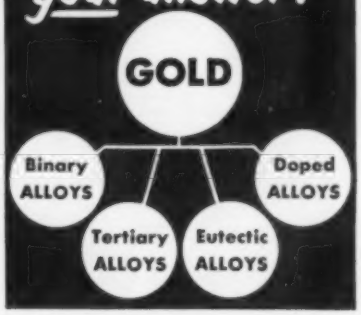
Is **PM²·X** *your answer?*



Let X equal your problem in electronics or atomics. Technic experience is that application of PM² (Precious Metal Plating Metallurgy) may be your solution.

ALLOY GOLD PLATING

Growing complexity of requirements in the electronic and atomic fields brings demand for gold coatings that have qualities other than 24K gold. Technic methods and equipment enable you to meet problems with a new tool — an exact metallurgy which alloys 24K plating gold with trace amounts, or more, of desired elements.

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We engineer and install all your requirements for precious metal electroplating with rigid scientific control. And our specialists are *your* specialists until your installation achieves optimum performance. Send us your problems — old or new — for Technic recommendations.

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THE LARGEST ENTERPRISE OF ITS KIND IN THE WORLD

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PRECIOUS METALS FOR INDUSTRIAL PLATING

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Mirror-bright finish in any thickness directly from the bath. Patented

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Restores contaminated cyanide plating baths to full, trouble-free operation. Patented

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Crystal-clear solution that produces mirror-bright deposits. Patented

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Brilliant, fine-grained non-tarnishing deposits.

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Only rhodium electroplating process that yields extra heavy compressively stressed deposits. Patent Pending

ACID GOLD PLATING PROCESS
Developed specifically for plating printed circuits. Mildly acid so that neither the laminate nor the adhesive at the inter-face of printed circuit boards are affected during the plating process.

Complete installation and servicing on all precious metals processes.

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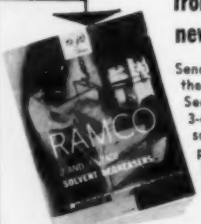
Q A **METAL PARTS CLEANING PROBLEMS?**

Get the answers RIGHT from RAMCO'S new BULLETIN!



Send for your copy of the Ramco Bulletin. See how Ramco 2- and 3-dip degreasers can solve your metal parts cleaning problems safely, efficiently, economically! Send today!

RAMCO EQUIPMENT CORP.
DIV. OF RANDALL MFG. CO., INC.
809 Edgewater Rd., New York 39, N.Y.

LIST NO. 128 ON INFO-COUPON PAGE 170

How Roll Coater *Pre-Painted* METAL SAVED MONEY AND IMPROVED QUALITY ON

PROBLEM:

Stello Products Company, Logansport, Indiana, manufacturer of tags, license and "booster" plates, had the problem of excessive direct labor charges. In the previous expensive method of making these items, plates had to be stamped from bare metal —and then cleaned individually—and spray painted on both sides. This method did not give the uniform quality demanded—and Stello turned to Roll Coater for a solution.

SOLUTION:

Roll-coated metal was tested by Stello Products Company. *Pre-painted* and *baked* on both sides, this metal eliminated *entirely* the cleaning and spray painting operations—withstood rigorous stamping tests—and relieved painting facilities for other jobs. Says J. C. Cotner, president of Stello Products Company, "Roll Coater metal is now saving us approximately 50% in direct labor costs—and is giving us the desired uniform quality in our plate production. It really solves our problem."

SEND FOR FREE BROCHURE and SAMPLE TODAY!

Roll Coater
INCORPORATED
PENDLETON, INDIANA

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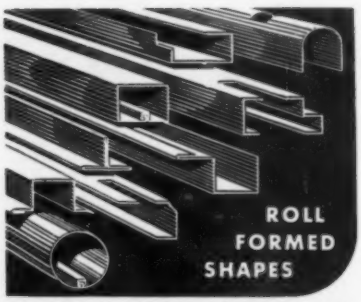

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MAIN OFFICE AND PLANT
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ARco

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Subsid. of Automotive Rubber Co., Inc.
ARco STEEL FABRICATORS • INC.
12542 BEECH ROAD • DETROIT 39, MICH.

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RUST-LICK IN AQUEOUS SYSTEMS

Grade "C-W-25"
Non-flammable
Non-toxic
Aqueous Oily Film Protects Ferrous Parts for Long Periods Indoor Storage

Write for free sample and brochure
Specify Grade "C-W-25"

PRODUCTION SPECIALTIES, INC.
755 BOYLSTON STREET
BOSTON 16, MASS.

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NEW...

STANDARD REFERENCE

For Superior Metal Treating and Finishing Products.

Send for your free copy of "ONE SOURCE" now!

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CHEMICAL COMPANY INC.

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the GRIES

MICRO-REFLEX

HARDNESS TESTER

Loads: 10 to 3000 gram with CARL ZEISS Optical System

Measurements: to 0.0001 mm. . . . Observations on Ground Glass . . . Projection: to 0.001 mm. . . . Many Unique, Very Important Features.

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Testing Machines Division

NEW ROCHELLE 3, N.Y.

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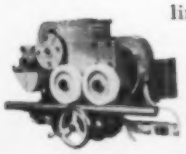
MARKING for any product!

Rubber type, logos and dies . . . imprinting units for rounds or sheets . . . for in-line marking of moving stock.



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Over 100 Years of Service to Industry

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A CABLE SPLICED IN 10 SECONDS!

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Complete Arc Welding Accessories

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make hardness tests ANYWHERE WITH THE NEWAGE TESTER

- CLAMPS, JAWS & BASE PLATE ARE ELIMINATED
- NO CONVERSIONS OR CALCULATIONS
- TEST ANY SIZE, SHAPE OR TYPE METAL
- NO SKILL REQUIRED
- SCALE READINGS IN ROCKWELL & BRINELL
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Many thousands used by industry and government. Write, wire or call for additional details and prices.

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- All Analyses
- Coated, Straightened
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Call Mr. Electrode . . . His years of experience and leadership in providing the *correct*—

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—place a trusted guarantee back of your welding operations.

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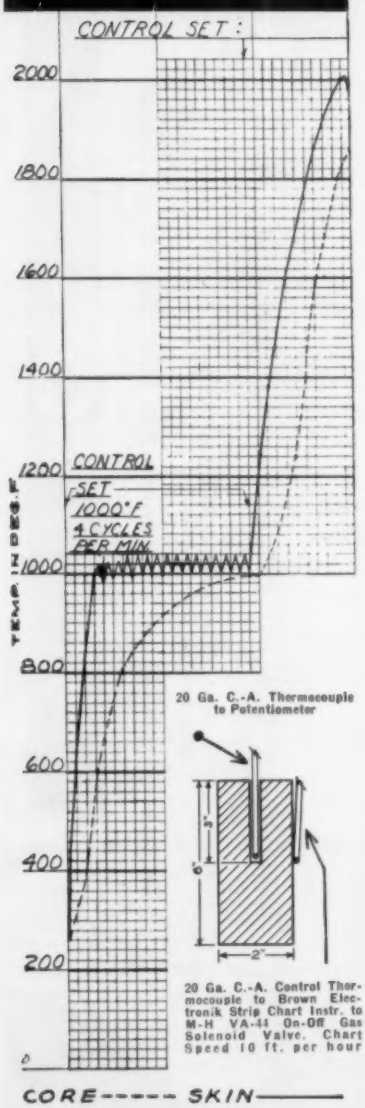
Firing Rate: 50,000 B.T.U. Per Sq. Ft.
Blower Air = 117 C.F.M.



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THE A. F. HOLDEN COMPANY
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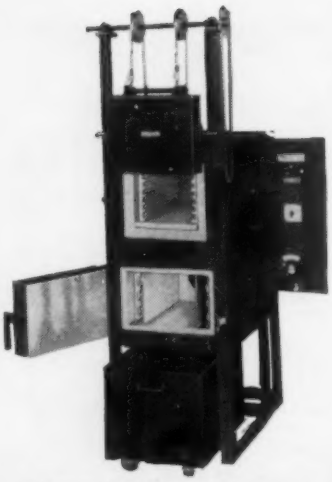

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Drawing furnace has a maximum of 800° F.* Quench tank included with the exception of the largest standard model.

	Chamber Size			Prices	
Model	H.	W.	L.	2000° F.	2300° F.
8055 A	6"	6"	12"	$ 865.00	$ 975.00
8055 B	9"	9"	18"	1325.00	1450.00
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*Also available up to 1250° F.

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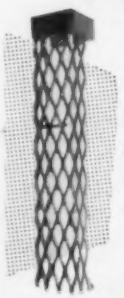

- INSTANT HEATING
- SHOCK-PROOF
- AVAILABLE IN ALL VOLTAGES —WATTAGES, ONE AND THREE PHASE

Available from your Electroplating Distributor

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RUST-LICK IN AQUEOUS SYSTEMS

Grade "B"
FERROUS METAL PROCESSING
Eliminates . . .

Rust
Fire Hazards
Toxicity
Dermatitis
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Write for free sample and brochure
Specify Grade "B"

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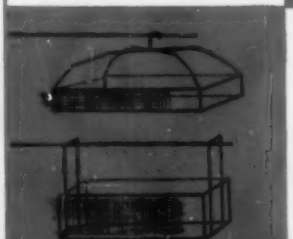

for ALL Industrial Uses

- Degreasing
- Anodizing
- Pickling
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ANY SIZE AND SHAPE • ANY DUCTILE METAL

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THE C. O. JELLIFF MANUFACTURING CORP.
SOUTHPORT • CONNECTICUT

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WIRETEX *fabricated*

PLATE POTS

Last longer.... cut operating costs
fast delivery..low cost

WIRETEX PLATE POTS withstand temperatures up to 2100°! Cut neutral or cyanide bath costs! Last 15 to 20% longer! Operating costs drop 25 to 35%! Down time is almost halved!

- All metals
- I.D. dia. up to 24" and larger
- Depths unlimited
- Dished bottom heads
- Overlapping seams
- Double x-ray quality weld, inside and out
- Heavy steel flanges
- Stress relieved
- Sand-blasted finish

Before you buy any salt pot, or if you have other heat and corrosion resistant problems —SEE WIRETEX.

Before you buy any salt pot, or if you have other heat and corrosion resistant problems—SEE WIRETEX.

Wiretex mfg. co. 5 Mason St., Bridgeport 5, Conn.
Specialists in Processing Carriers Since 1932

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PRODUCED AND PRICED RIGHT FOR YOUR ELECTRIC FURNACE NEEDS

DYNA-TROL

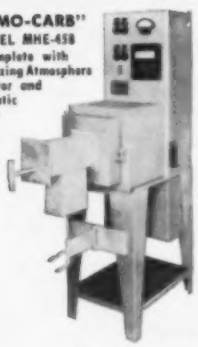
MODEL NO.	FIRING CHAMBER (H.W.D.)	PRICE (300° to 2000°)	PRICE (400° to 2300°)
P48	4½"x4½"x6"	$90.00	$110.00
P79	6"x6"x9"	$205.00	$225.00
P918	9"x9"x18"	$480.00	$528.00
P414	14"x14"x14"	$525.00	$603.25
P124	12"x12"x24"	$715.00	$822.25
P818	18"x18"x18"	$775.00	$887.50
P136	18"x18"x36"	$1125.00	$1312.50

Automatic Controls Available on all Models

Model P-79

- Infinite zone temperature control
- Zone temperature indication by Pyrometer Selector Switch
- Automatic hold and cut-off instrument available
- Patented element holders
- Infinite variety of time-temperature curves obtainable
- Rugged construction

"ATMO-CARB"
MODEL MHE-458
Complete with Carburizing Atmosphere Generator and Automatic Control



$1325.00
Other Sizes and Arrangements Available

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Chester 77, Pa.

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Upton Salt Bath
Hi and Low Heat
Price $1975 Each

Our stock is constantly changing! Before you buy any furnace or accessory, call us collect and let us show you how to save money! (Money-Back Guarantee). We pledge that any unit we advertise is in stock at one of our warehouses at the original time of publication. However, they are subject to prior sale, so act now!

METAL TREATING EQUIPMENT EXCHANGE, INC.
9825 GREELEY ROAD
DETROIT 11, MICHIGAN

LIST NO. 142 ON INFO-COUPON PAGE 170

WANTED

SIR PLUS FURNACES

REWARD

WE PAY CASH FOR SURPLUS INDUSTRIAL FURNACES AND RELATED APPARATUS

SURPLUS FURNACES FOR SALE

BOX TYPE

24x36x18	Lindberg	50KW	2000°F
36x72x23	G.E.	72KW	2000°F
48x84x24	American	100KW	1850°F
24x36x14	Surface	Gas	1850°F
54x96x24	Surface	Gas	1850°F

PIT TYPE

25x36	Lindberg	66KW	1250°F
28x28	Lindberg	52KW	1250°F
48x72	Lindberg	Gas	1250°F
48x96	Surface	Gas	1250°F
48x96	Lee Wilson	Rad. Tube	

CONVEYOR TYPE RECIRCULATING

36x33'x12	Despatch	MshBlt Gas	875°F
27x15'x12	R&S	MshBlt Gas	1250°F
48x20'x12	Surface	PltBlt Gas	1000°F

BOX TYPE RECIRCULATING

36x36x36	Despatch	Gas	1250°F
72x12'x42	Lindberg	Gas	1250°F
24x36x24	Lindberg	45KW	1400°F
36x48x24	Lindberg	45KW	1250°F
66x16'x76	Lindberg	180KW	1250°F

PIT TYPE CARBURIZERS

10x20	Hevi Duty	14KW	1800°F
15x18	L&N Homo	30KW	1800°F
20x36	L&N Homo	72KW	1800°F
25x36	L&N Homo	85KW	1800°F
20x48	L&N Homo	85KW	1800°F

ROLLER HEARTH

28"	G.E.	17'htg.	70'C.	320KW	2050°F
28"	G.E.	28'htg.	90'C.	497KW	2050°F
62"	G.E.	18'htg.	45'C.	655KW	1650°F

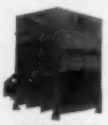
SEND FOR COMPLETE LIST

THE JOE MARTIN CO., INC.
19256 John R. St. TWinbrook 2-5500 Detroit 3, Mich.

LIST NO. 160 ON INFO-COUPON PAGE 170

KOZMA *Eventemp* RECIRCULATING FURNACES

PIT TYPE



OVEN TYPE

PROVIDE CLOSE TEMPERATURE CONTROL FOR:

- Drawing, tempering and stress relieving
- Heat treating of brass and copper
- Solution heat treating and aging of aluminum
- Heating aluminum for forging

EVENTEMP recirculating furnaces offer highest heating efficiency plus the convenience of push-button operation. Available in either gas fired or electric models in a wide range of sizes and capacities, KOZMA *EVENTEMP* FURNACES assure accurate temperature control within a range of 300° to 1650° F.

For complete information write:

J. A. KOZMA COMPANY, 2471 Wyoming
Dearborn, Michigan

Electrosalt Furnaces . . . Radiant Forging Furnaces . . . Eventemp Pit and Oven Furnaces . . . Gas or Oil Salt Bath Furnaces . . . Melting and Smelting Furnaces . . . Gas or Oil Roller Hearth, Chain, Pusher and Rotary Hearth Furnaces.

J. A. KOZMA Company

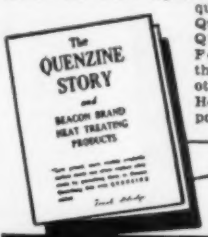
INDUSTRIAL PROCESSING FURNACES SINCE 1928

LIST NO. 158 ON INFO-COUPON PAGE 170

FREE

the QUENZINE STORY

Low priced, more readily available carbon steels can often replace alloy steels when quenched in Beacon Quenching Oils with QUENZINE added. For information on this new additive and other Beacon Brand Heat Treating Compounds write to . . .



KELCO

ALDRIDGE INDUSTRIAL OILS, Inc.

3401 W. 140th St., Cleveland 11, Ohio

LIST NO. 29 ON INFO-COUPON PAGE 170

END POT FAILURE

Switch to *scheduled* pot maintenance with low-cost pressed-steel pots for lead, salt, cyanide, oil-tempering, metal-melting. Can't turn suddenly defective, because no faulty steel survives drawing. Request catalog from Eclipse Fuel Engineering Co., 1018 Buchanan St., Rockford, Ill.

Eclipse INDUSTRIAL COMBUSTION DIVISION

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HAWKRIDGE METALS CORPORATION

Producers and Sellers of

TITANIUM POWDER

−40 to +300 mesh

High Purity	99.2% Pi
Commercial	98.6% Pi

North Hampten
New Hampshire

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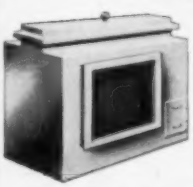
ARco AIR WASH SYSTEMS

PLATING • PICKLING • METAL CLEANING *FUME SCRUBBING*



- Reasonable initial cost . . . economical in operation . . . no moving parts . . . efficient in performance . . . compact—requires little space . . . standard units—7200 to 57600 C.F.M. Write Dept. "MP" for complete information.

ARco

AUTOMOTIVE RUBBER CO. • INC.
12550 BEECH ROAD • DETROIT 39, MICH.

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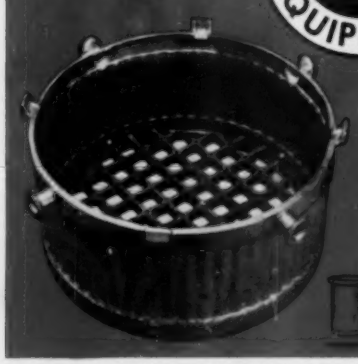
STANWOOD HEAT TREATING EQUIPMENT RETORTS and STACKING BASKETS

• REPRESENTATIVES IN PRINCIPAL CITIES



of new Cor-Wal construction give you:

- Lighter weight—yet stronger
- Longer service life
- Sides are heat resistant corrugated rolled metal
- Basket grid, grid supporting ring and top ring are of high temperature cast alloy
- Proved in exhaustive tests on the job

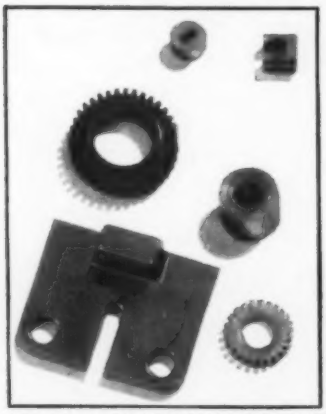
WRITE FOR DETAILS

STANWOOD CORPORATION
4817 W. Cortland St., Chicago 39, Ill.

LIST NO. 12 ON INFO-COUPON PAGE 170

HIGH-DENSITY SINTERED METAL PARTS

carburized tensile strength to 200,000 psi.



Supermet combines the economy of powder metallurgy with the properties of controlled carburization to give you solid steel parts at low cost. Seven ranges of properties available in electrolytic iron; we also invite stainless steel parts. As an indication of accuracy, we are currently pressing AGMA commercial class 4 spur gears. Send a part print for evaluation.

Supermet Division

GLOBE INDUSTRIES, INC.

1465 Cincinnati St. Dayton 8, Ohio

free technical literature

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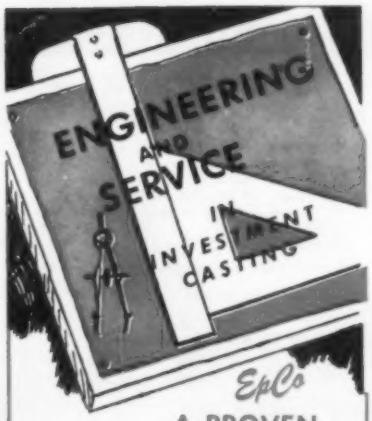

EpCo

A PROVEN DEPENDABLE SOURCE

FOR BETTER GRADE INVESTMENT CASTINGS IN FERROUS AND NON-FERROUS METALS

INVAR CASTING Special Feature—Nickel content held to 35% minimum—36% maximum

STAINLESS STEEL PART for milk bottling unit formerly machined from solid stock. Only finish operations required are reaming small dia. of counterbored hole and drilling and tapping for set screw.

ENGINEERED PRECISION CASTING CO.

MORGANVILLE, N. J.

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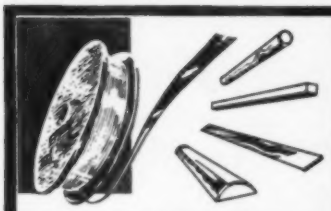

ROUND, SQUARE, FLAT AND HALF-ROUND WIRE FOR MASS PRODUCTION OF SMALL PARTS

Beryllium Copper • Bronzes
Other Non-ferrous Alloys
Rounded or square edges.
Available with hot-tinned finish for solderability.
Write for descriptive folder.

LITTLE FALLS ALLOYS
INCORPORATED
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CORROSION RESISTANT

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Telephone: CLifford 6-2300
Direct N.Y. 'phone Wisconsin 7-9041
Direct Phila. 'phone WAlnut 5-3660

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ELECTROMARK

Electrochemical etcher for faster, better, lower cost permanent metal markings!

THE ELECTROMARK CORP.
2093 E. 19th St. Cleveland 3, Ohio

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PACIFIC ENGINEERED FURNACES

MEET YOUR TOUGH SPECIFICATIONS

Illustrated is the discharge end of a completely automatic Pacific Normalizing and Carbon Restoration Furnace with a capacity of 1500 lbs. per hour and operated by only one man. Prepared atmosphere generator is at left.

Pacific ENGINEERS . . . BUILD . . . SERVICE all types of industrial heating equipment. Our engineers are practical shop men with years of experience. We believe in followup after installation.

FOR COMPLETE INFORMATION ON OUR SERVICES —WRITE OR CALL

THE Pacific INDUSTRIAL FURNACE CO.

24680 Telegraph Road, Detroit 19, Michigan
Phone: Kenwood 3-6900

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SPECIAL SERVICE ON *HIGH SPEED* STEEL FORGINGS

FAST NATION-WIDE SERVICE ...YOUR STEEL OR OURS

Complete Source For Forged Products Up To 4000#
Rings, discs, spindles, bars or special shapes to your specifications.

28 Years Of Specialized Experience
In production of high speed tool and alloy steel flat die forgings.

Ample Stocks Of Steel Always On Hand

Expert High Speed Steel Blacksmiths

Call or write for free cost quotation on your forging requirements

Smith-Armstrong FORGE, INC.

1209 MARQUETTE ROAD • HENDERSON 1-0320 • CLEVELAND, OHIO

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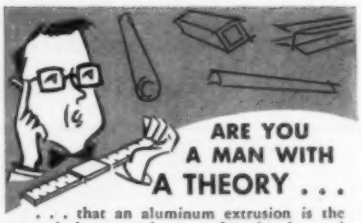

ARE YOU A MAN WITH A THEORY . . .

. . . that an aluminum extrusion is the practical approach to a functional metal parts application . . . at a savings in time and money, and without loss in quality? In fact, the properties — you theorized — of extruded aluminum would even be better? If so, G.E.I.'s engineers are ready to consult with you — without obligation, on one part or a million — to determine how practical your idea is. G.E.I. engineers specialize in adapting extruded aluminum to *new* functional roles.

GENERAL EXTRUSIONS, INC.

3040 LAKE PARK RD., YOUNGSTOWN, OHIO. STerling 6-3081

Missouri, S. Illinois Representative: Frank May Co., 4378 Lindell Blvd., St. Louis 8, Mo.
Michigan Representative: Howard B. Jones, 15842 Kentfield Ave., Detroit 23, Mich.
Southern Distributor: General Extrusions of Memphis, Inc., 4462 Summer Ave., Memphis, Tenn.

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Need Help Designing That Aluminum Extrusion?

TEAM UP with JARL

THERE'S A WORLD OF DIFFERENCE

The *difference* starts the moment you meet the Jarl salesman. He's an engineer . . . well qualified to make on-the-spot recommendations in designs. Team up with Jarl and you'll get the right shapes made to most exacting design specifications. You'll be sure of close die control . . . quality safeguards every step . . . on-time deliveries. Send for our stock die catalog or send rough sketches for assistance with your design.

ANODIZING

JARL EXTRUSIONS, INC.
Dept. MP, Linden Ave. • East Rochester, N. Y.

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WHITELIGHT

MAGNESIUM

your comprehensive independent mill source of magnesium alloy . . .

RODS	⅛" dia. to 6½" dia.
BARS, STRIPS	.022" min. to 7¾" max.
SOLID SHAPES	.022" min. to 6½" circle
TUBING	¼" O.D. to 6" O.D.
HOLLOW SHAPES	¼" to 6½" circle
PLATE and SHEET	.092" to 3" thick

ALLOYS		ALLOYS
AZ10	WHITELIGHT MAGNESIUM	ZK60
AZ31		ZK30
AZ51		M-1
AZ61		HK31
AZ81		HM21

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82 Moultrie St., Brooklyn 22, N.Y.

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HOOVER

SPECIALISTS IN THE FIELD OF

Die Castings

SINCE 1922

Aluminum and Zinc

HOOVER

THE HOOVER COMPANY
Die Castings Division
North Canton, Ohio
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7301 Euclid Avenue, Cleveland 3, Ohio

Please send further information, as checked at the right, on the advertisements in the Bulletin Board with numbers I have listed below—

(Bulletin Board Item Number)	(Please check) Send Catalog or Engineering Data	Send Price Info	Nearest Source of Supply
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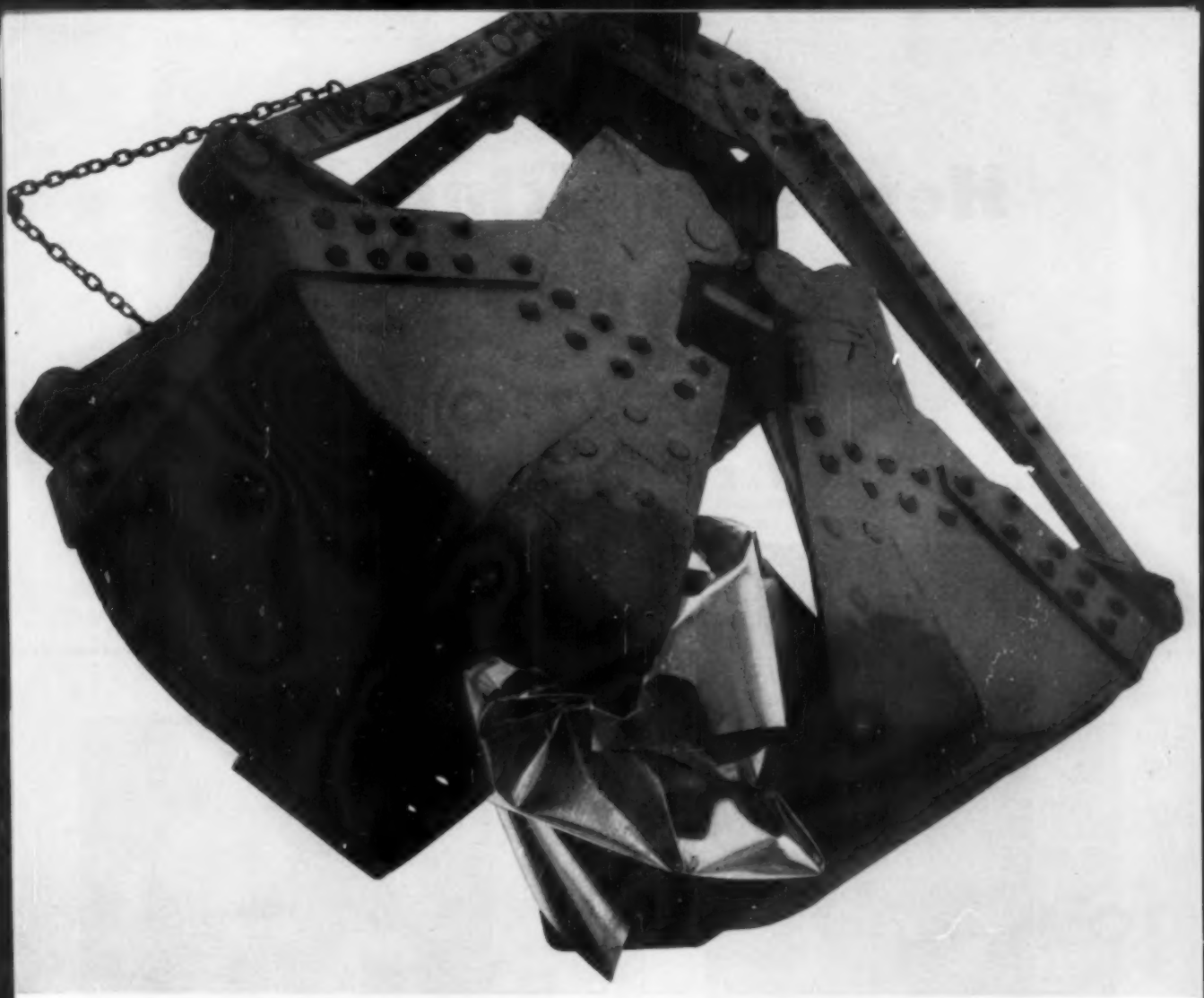


SQUEEZE PLAY FAILS TO SCORE AGAINST WEIRKOTE®

Crun-n-n-ch!

For brutal, iron-jawed pressure, a steam shovel has few equals. Here, in this crushing grip, Weirkote's zinc coating undergoes a murderous test.

Yet at every crease, at every tortured angle of this crumpled mass, the zinc remains an integral part of the steel. There is not one sign of flaking anywhere!

No wonder strenuous forming operations such as lock seaming are child's play, for Weirkote can be worked to the very limits of the steel itself!

No wonder parts fabricated from it require no painting, plating or redipping to guard against corrosion. Weirkote parts can be stamped, drawn or spun well in advance of use, and stored without danger of rust.

And NOW, Weirkote is treated to inhibit wet storage (white oxide) stain.

Why not find out what Weirkote's benefits can mean to you?

Free Weirkote Booklet! Send for all the facts on Weirkote. Write Weirton Steel Company, Dept. S-6, Weirton, West Virginia

WEIRTON STEEL COMPANY

WEIRTON STEEL COMPANY

WEIRTON, WEST VIRGINIA

a division of

NATIONAL STEEL CORPORATION

Here's the kind of service you get . . .

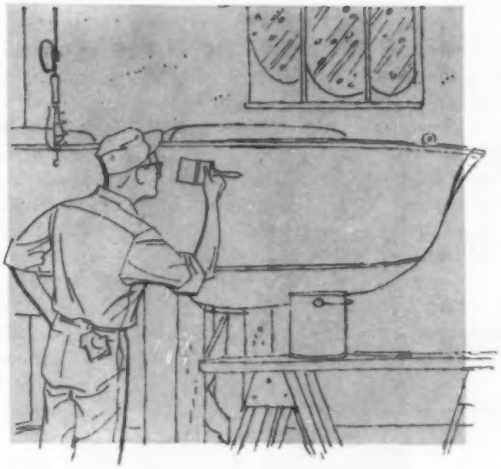
with HONEYWELL instrumentation

Bill Lewis, typical service engineer, proves how you can depend on Honeywell for fast, on-the-spot service even in emergencies.

3 It took Bill two hours to drive to the plant through the storm. He spotted the trouble immediately; a thermocouple and its protecting tube had burned out. It might have meant four to five thousand dollars' worth of damage.

Honeywell service begins when you first decide you need instruments, and continues long after they're installed. It includes:

- Preliminary engineering, even before specifications are written.
- Application engineering for installation and startup.
- Service engineering help from your nearby Honeywell branch.
- Periodic service and swift help in emergencies.
- Training of your operators at the Honeywell Instrumentation Education Center.



1 Bill Lewis, service engineer at Honeywell's Fort Wayne branch, was in his garage, touching up the paint on his 13-foot outboard. The bowling match had been called off that night because of the snowstorm, and Bill was glad to be home.

2 At 9:30 a call came from the Crosby Laughlin Division of American Hoist and Derrick Company in Fort Wayne. A controller on a galvanizing kettle wasn't working and unless it was fixed fast, the pot would either freeze or burn out. Bill said he would be out right away.

4 Bill didn't have a thermocouple with him that would fit, so he improvised a temporary couple and protecting tube and got the system going. Early the next morning he called the Honeywell branch in Indianapolis and had the correct thermocouple and tube shipped quickly to the plant. Next day, he carefully checked out the entire installation.

5 Now, Crosby Laughlin Division is signed up with the Honeywell Periodic Service Plan, and its complete instrumentation is checked and serviced every month. Any spare parts needed are now available at Honeywell's Fort Wayne branch. Bill hasn't had to make another emergency call to the plant since.

Around-the-clock help in emergencies is but one of many Honeywell services that give you extra value for your investment in instruments. Get the complete service story from your near-by Honeywell field engineer. He's as near as your phone.

MINNEAPOLIS-HONEYWELL REGULATOR CO.,
Industrial Products Group . . . Brown Instruments,
Wayne and Windrim Avenues, Philadelphia 44, Pa.

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First in Controls

Hydrogen in Steel Mill Slags

Digest of "Hydrogen in Steelmaking Slags", by J. H. Walsh, J. Chipman, T. B. King and N. J. Grant, *Journal of Metals*, A.I.M.E., Vol. 8, November 1956, p. 1568-1576.

THE DIFFICULT PROBLEM of determining hydrogen in steel mill slags is fully reviewed in this paper. Methods and equipment to carry out this determination, the technique of establishing the blank correction, and the calibration of the apparatus are described in detail. All work was done in a vacuum furnace designed to minimize contamination from water vapor in air or the materials of which the furnace was constructed.

Calibration was accomplished by determining the hydrogen evolved from minute amounts of borax ($NA_2B_4O_7 \cdot 10H_2O$), which contains 5.27% hydrogen. Small amounts of this compound were added to slag samples. This practice answered two questions: whether all the hydrogen contained in the slag sample was released and whether all the hydrogen released reached the gas analysis section. Molten synthetic slag samples containing 40% CaO, 40% $Si0_2$ and 20% Al_2O_3 were treated at 1370 to 1550° C. (2500 to 2820° F.) with a mixed gas containing controlled mixtures of water vapor, hydrogen, and nitrogen. This was done in a special vertical Globar tube-type furnace. To assure approach to equilibrium on both sides, the slags were held at temperature for six hours in air or steam, respectively, for runs with increasing or decreasing hydrogen content. The treated slags were then quenched in mercury or water and later analyzed for hydrogen. About 5 to 6 hours were required for saturation of the slags with hydrogen.

Analyses of the synthetic slags showed that the hydrogen content in parts per million (0 to 80) varied directly as the square root of the partial pressure of the water vapor present at the time of slag treatment. The amount of hydrogen absorbed by the slags was entirely dependent on the partial pressure of the water vapor in the gas stream and apparently quite independent of the partial pressure of hydrogen in the gas mixture. Dry mixtures of nitrogen and hydrogen caused no increase in hydrogen content of the slag.

Later studies of actual industrial steel mill slags were then made on basic openhearth, acid openhearth, and basic electric furnace slags. The hydrogen content of the synthetic slags (40% CaO, 40% SiO_2, 20% Al_2O_3) was about 70 to 80 ppm.; a 62% MnO, 38% SiO_2 slag contained about 40 to 42 ppm.; basic openhearth slag, 28 to 35 ppm.; basic electric slag, 19 to 24 ppm.; acid openhearth slag, 10 to 14.8 ppm. Less active boils and greater slag viscosity in acid openhearth conditions are cited as possible reasons for the much lower hydrogen content of acid openhearth slags. The authors also state that the hydrogen in the slag is probably near equilibrium with hydrogen in the metal bath; this would indicate

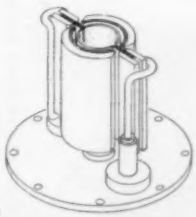
(*Continued on p. 176*)

NEW MODEL 420 BREW HIGH VACUUM FURNACE

successfully completes its first in-plant production runs.

2200°C (3992°F) continuous operation —at a vacuum of .01 to .05 microns — is provided by the BREW 420 High Vacuum Furnace for sintering, brazing, bright annealing and melting.

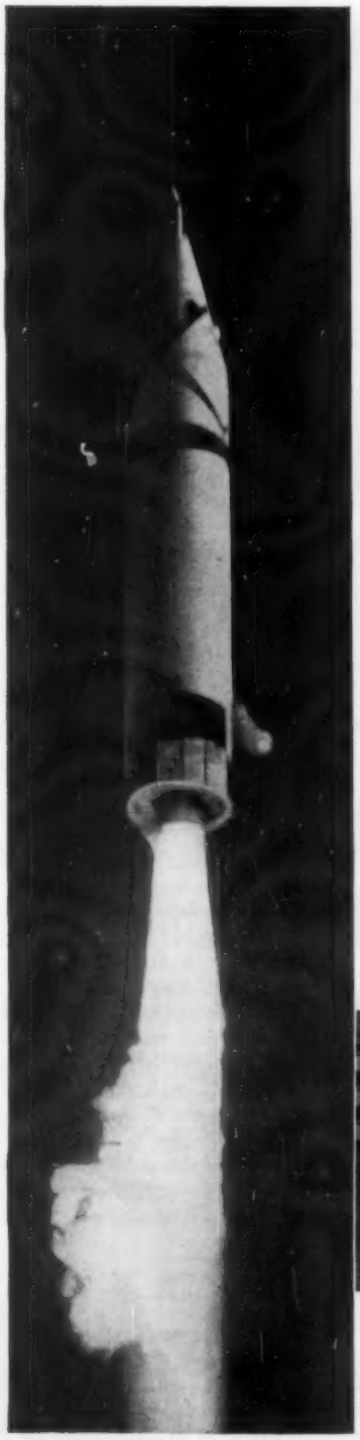
RIGHT: Drawing of high temperature heating element assembly, showing double-clamped elements (3" dia. x 6" high) made of tantalum, tungsten or molybdenum. No refractory materials are used in the BREW Model **420.**



MODEL 42[illegible] BREW
High Vacuum Furnace

designed and manufactured by
VACUUM FURNACE DIVISION
RICHARD D. BREW & CO., INC.
100 AIRPORT ROAD
CONCORD, NEW HAMPSHIRE

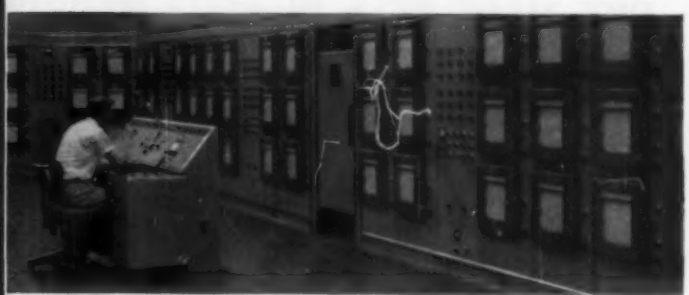
Specification pages completely describing the BREW Model 420 Vacuum Furnace will be mailed upon request.



When the stakes are high...

"Accuracy, reliability and versatility are the major considerations for instrumentation here at Redstone," says Fritz Weber, Chief of the Instrumentation Test Section, Army Ballistic Missile Agency. "During tests that may involve hundreds of thousands of dollars in equipment, supplies and manpower, a failure of the data recording equipment can result in a total loss of the run.

"In our strip chart recording room, we have over a hundred L&N Speedomax G modified adjustable instruments. All are equipped with retransmitting slidewires so that data can be fed into a Millisadic data system for storage and transmission to IBM equipment. Recorders are so equipped that they can be controlled from a central console. There, the operator can select the test site from which data is to be received and the method of data handling to be used. Before a test is started up, all 132 recorders can be standardized by a single button."



Vital data on Jupiter and Redstone Missile assemblies are supplied by 132 Speedomax G precision Recorders. As part of an exhaustive testing program, these data help guide ABMA's scientists in missile-firing.

"New Horizons", *L&N's Tech. Pub. ND46 gives data on circuitry, and performance characteristics of Speedomax instruments. Get a copy from your nearest L&N Office or from Leeds & Northrup Co., 4927 Stenton Ave., Phila. 44, Pa.*

LEEDS & NORTHRUP
Instruments — Automatic Controls • Furnaces

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H. K. PORTER COMPANY, INC.
RIVERSIDE-ALLOY METAL DIVISION

Hydrogen . . .

a lower hydrogen content for acid steel as compared to basic steel.

Analyses of synthetic and industrial slags for hydrogen by an adaptation of the technique used for steels lead to the following general conclusions:

1. The solubility of hydrogen in synthetic slags is proportional to the square root of the partial pressure of water vapor in the atmosphere in contact with the slags.

2. Hydrogen in slags results from reaction of the slag with water vapor; slags do not dissolve significant amounts of hydrogen from hydrogen gas.

3. Within the ranges encountered in practice, temperature and slag composition have minor effects on the solubility.

4. Acid openhearth slags contain less hydrogen in practice than basic openhearth slags. In addition, the hydrogen content of acid slags remains far from equilibrium with the furnace atmosphere during a heat. With basic slags the hydrogen content of the slag rises during a heat to almost the equilibrium value at tap.

5. Basic electric slags are closer to equilibrium with the furnace atmosphere, and the hydrogen content can decline during a heat.

6. In all practices the slag is not at equilibrium with the steel but the carbon boil prevents the hydrogen content of the steel from rising.

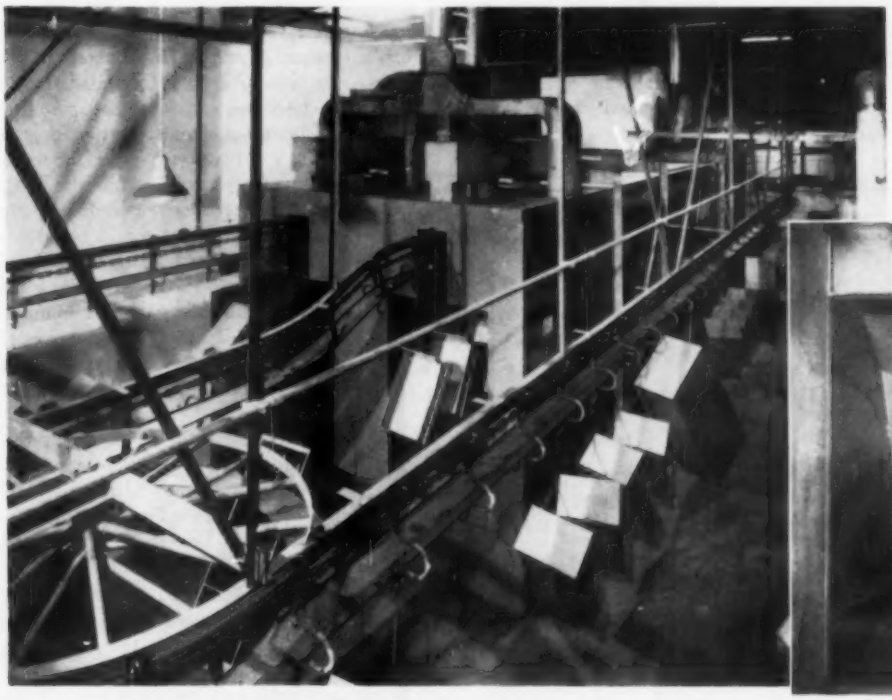
7. Acid slags pick up hydrogen from the atmosphere and transfer hydrogen to the steel at lower rates than basic slags. This is probably to be attributed to the higher viscosity of acid slags.

E. C. WRIGHT

TEMPERATURE MEASUREMENT

Industrial temperature measurement with thermocouple pyrometers, with total radiation and optical pyrometers, with resistance thermometers and filled systems thermometers. W. E. Belcher, Jr., D. Robertson, W. F. Hickes—64 pages—6x9—illustrated—paper cover—$1.00. *Clip and send to Technical and Engineering Book Information Service, 7301 Euclid Avenue, Cleveland 3, Ohio.*

THIS DESPATCH FINISHING SYSTEM PROVIDES MAXIMUM PRODUCTION with MINIMUM MANPOWER



Overhead conveyor (photo at left) carries component parts 500 feet through a three-stage washing cycle, a drying oven, a paint spray booth, and the bake oven shown here.

Spray booth (lower photo) where each part is painted from opposite sides, features two water curtains and an air replacement system.

Semi Automatic Operation Speeds Work Flow for Office Furniture Manufacturer

Fifty thousand pounds a day production with only nine employes—that's the potential for the DESPATCH Finishing System recently installed in the new 37,000-square-foot Art Steel Company, Inc., plant at Los Angeles, Calif.

Consistent surface texture, even color, with a finish that is neither soft nor brittle and well bonded to the metal, are basic requirements for high quality in the manufacture of high quality steel office furniture. Only accurate timing and temperature controls, possible with DESPATCH equipment, are equal to the job. The custom-built installation shown, above, was planned to meet all requirements.

Occupying only one-sixth the total plant area, reliable DESPATCH equipment keeps production moving through each finishing stage with less than one hour required for the entire finishing operation.

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PIONEERS IN ENGINEERING FINISHING SYSTEMS FOR INDUSTRY

Mild Steel in Nuclear Applications

Digest of "Low Manganese Steels for Nuclear Applications", by H. F. Beeghly, *Journal of Metals*, A.I.M.E., Vol. 8, December 1956, p. 1664-1670.

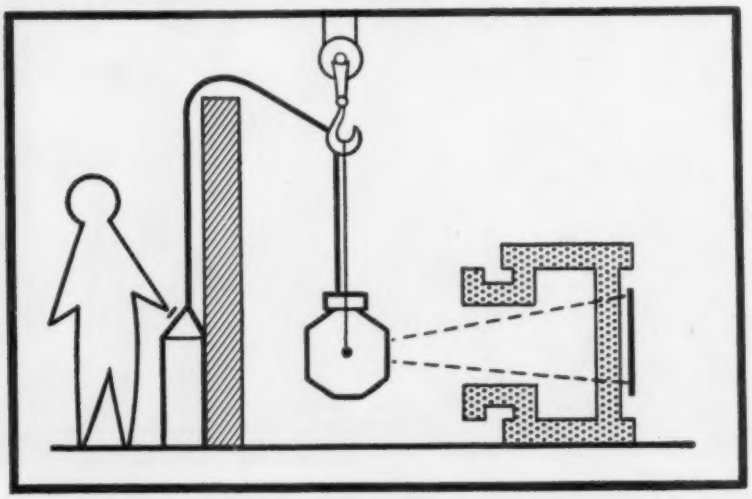
THE ADVENT of nuclear engineering and technology has brought about many new ideas and new methods in processing and fabrication. Most of these innovations had to do with the "new" metals, such as zirconium, hafnium, beryllium, uranium, plutonium and their alloys. But now, the stalwart of our time, mild steel, is yielding to the new demands of the atomic age. It appears that mild steel can be produced with a reduced cross section. This does not refer to the cross-sectional area of an I-beam, but to the physical property known as the microscopic absorption cross section for the thermal neutrons. This property is measured in units of barns (one barn equals 10^{-24} sq.cm.).

Assuming that a large cross section, just like overweight, is undesirable, it is shown that manganese is the major offender common to all grades and types of steels. Manganese, with a cross section of 12.0 barns, is present from about 0.25% in low-carbon steel to about 2.5% in 18-8 type stainless steels; no other element has a cross section greater than 2.4 barns which is the cross section for iron. Aside from lowering the cross section, a reduction in manganese content would be advantageous in all applications of mild steel where sources of radioactive isotopes must be kept at a minimum. Manganese is the major source of high-energy radioactive isotopes in common steels. It is the presence of radioactive isotopes created during the exposure of the metal to neutrons that makes the postirradiation examination and study of all materials, including mild steel, so difficult. Depending on the level of induced radioactivity, all post-irradiation tests must be performed by remote control. The difficulties may be visualized by considering the operations that are needed to produce one satisfactory photomicrograph. Even etching solutions which worked well for pre-irradiation samples may not be useful at all for postirradiation samples of the same material.

In this paper the author presents the results of pre-irradiation standard tests to evaluate experimental heats in which the manganese content was reduced to 0.10 to 0.15% and was replaced by titanium or zirconium with aluminum. The latter two elements have the very desirable low cross sections of about 0.2 barn, while titanium has a cross section of 5.6 barns but has been added to the steel in very small amounts (in many cases less than 0.25% by weight). Each heat (openhearth) was cast into a 7000-lb. ingot and converted to a finished product on full-size mill equipment under customary processing conditions for comparable grades with normal manganese content.

The purpose of the program was to develop substitutes for three common grades of mild steel: first, the boiler plate grade A 212 B; second, grade A 106 commonly used

(*Continued on p.* 180)



GAMMA RADIOGRAPHY THROUGH 9 INCHES OF STEEL!

Nuclear Systems' Model 1060 Multitron, an industrial gamma radiography machine, gives results faster than a 1,000,000 volt X-ray machine and comparable to those of a 2,000,000 volt X-ray machine . . . *at a small fraction of X-ray machine cost.*

The Model 1060 is designed to safely handle up to 1,000 curies of Cobalt 60. Provided with completely fail-safe automatic controls, the beam-producing 1060 is operated from a remotely located console and is capable of making radiography exposures through nine inches of steel and upwards.

Dominion Foundries and Steel, Limited, Hamilton, Canada, uses the 1060 successfully and efficiently for quality inspection of extremely heavy steel castings.

Call on Nuclear Systems for your radiography equipment needs. Offices in Philadelphia, Chicago and San Francisco. Sales representatives in principal cities. Catalog on request.

Visit our booth at the Atom Fair, Chicago, March 17-21.

NUCLEAR SYSTEMS
A DIVISION OF THE BUDD COMPANY Philadelphia 32
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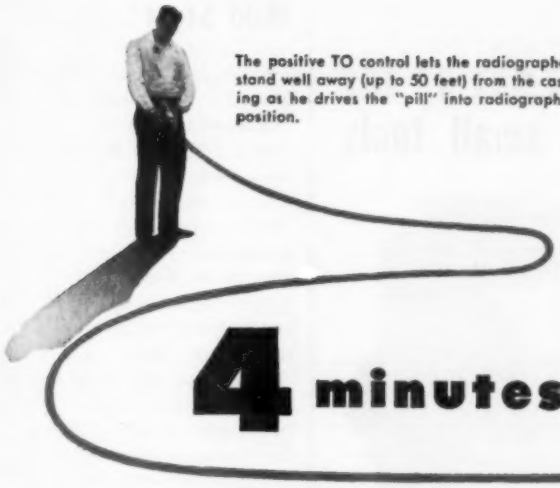
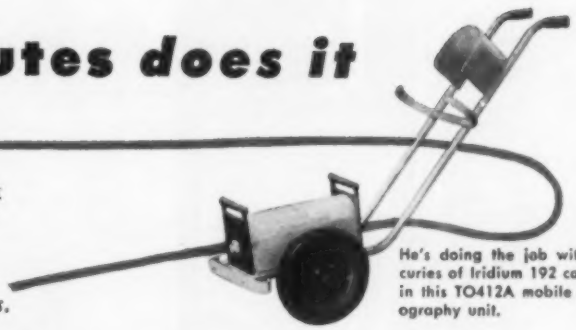


The positive TO control lets the radiographer stand well away (up to 50 feet) from the casting as he drives the "pill" into radiographic position.

4 minutes *does it*



He's doing the job with 50 curies of Iridium 192 carried in this TO412A mobile radiography unit.

The man up there radiographing that 2" thick steel casting down there will have the job done in four minutes.

That's how fast modern gamma radiography is.

The isotope he's using (Iridium 192) will give him 2% sensitivity, too. Matter of fact, you can easily get 2% sensitivity in sections up to 6" of steel, brass, copper, bronze . . . even *lead* . . . when you match the isotope to the job.

Makes no difference what you *make* or *buy* or *sell* (plastics, light metals, fabricated parts, assemblies—the list is endless) if it needs radiographic "seeing into" for quality control, we have the machine (gamma or x-ray) to do it most efficiently.

If *you are* confronted by an inspection problem why not let our consulting radiographers see what they can do for you? It will cost you nothing, may save you a lot. Call your local Picker* representative or write us outlining the situation.

Picker x-ray

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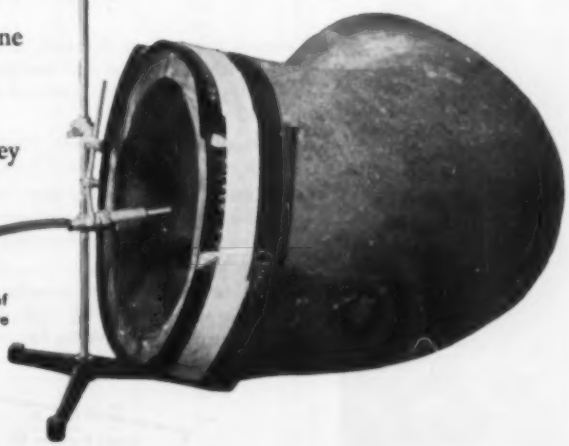

One "shot" radiographs the entire girth of the casting. Picker Flexible Film Holders are quickly taped on, quickly removed.

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ANDREX lightweight portable x-ray units—130 KV, 160 KV, 200 KV, 260 KV and *Andrescope* X-ray Stress Analyzer.

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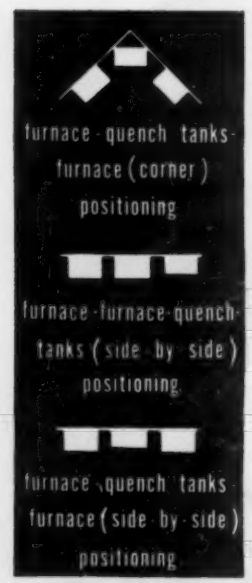
Now ...a complete set-up for heat-treating small tools

Waltz small tool furnaces


furnace-quench tanks-furnace (corner) positioning
furnace-furnace-quench tanks (side-by-side) positioning
furnace-quench tanks-furnace (side-by-side) positioning

Contains a pre-heat furnace, a high-heat furnace and quench tanks in a unit designed for convenient positioning in your shop. Furnace sections are equipped with casters.

Temperature range permits treatment of all high speed steels including cobalt type.

Waltz small tool furnaces are "money makers" in many shops throughout the country. Enjoy the lucrative advantages of heat-treating facilities right in your own shop.

A complete line of Waltz standard or special heat-treating furnaces using all types of fuels are built to suit your requirements. Write for comprehensive illustrated bulletins.

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Mild Steel . . .

for seamless pipes; and third, the low-alloy high-tensile grade A 242.

Elevated-temperature tensile data (up to 1300° F.) show that the low-manganese material was generally stronger and somewhat less ductile than comparable grades with normal manganese content. The low-manganese steels are also less susceptible to strain aging. Weldability tests were made by joining the low-manganese steels to commercial A 212 plate and to stainless steel Type 347 and Type 304. Subsequent mechanical tests showed that the low-manganese material welded as well as or better than comparable commercial normal manganese grades. The effect of hydrogen on the low-manganese grades was not studied and postirradiation data will be reported at a later date.

F. Forscher

Nonmetallic Inclusions in Steel

A survey of the nature and origin of the common types of nonmetallic inclusions. Gives the origin of inclusions in ingots under all conditions. M. Baeyertz — 130 pages — cloth — 6x9 — $4.00. *Clip and send to Technical and Engineering Book Information Service, 7301 Euclid Avenue, Cleveland 3, Ohio.*

Isolating Inclusions in Steel

Digest of "A New Electrolytic Cell for Isolating Carbides and Nonmetallic Inclusions in Steel", by N. Backstrom, S. Heiskanen, and U. Ilme, *Jernkontorets Annaler*, Vol. 140, No. 10, p. 812-815; translated and digested in *Engineers' Digest*, Vol. 17, December 1956, p. 523, 530.

In the course of experimental investigations on the structure and constitution of ferrous alloys it is frequently desirable to isolate samples of carbides or nonmetallic inclusions for examination and analysis. The method most commonly used is electrolytic dissolution under conditions permitting selective solution of the matrix structure leaving the carbide

(*Continued on p.* 182)

Columbia Tool Steels for 1957-58
with A.I.S.I. Identification and Type Classification of Tool Steels

HIGH SPEED TOOL STEELS

TUNGSTEN BASE — TYPE SYMBOL T

GRADE	Type	Identifying Elements, In Per Cent									
		C	Mn	Si	Cr	Ni	V	W	Mo	Co	Cb
CLARITE	T1	.70	—	—	4.00	—	1.00	18.00	—	—	—
VANITE	T2	.80	—	—	4.00	—	2.00	18.00	—	—	—
	T3	1.05	—	—	4.00	—	3.00	18.00	—	—	—
ACMITE	T4	.75	—	—	4.00	—	1.00	18.00	—	5.00	—
COBITE	T5	.80	—	—	4.00	—	2.00	18.00	—	8.00	—
	T6	.80	—	—	4.50	—	1.50	20.00	—	12.00	—
	T7	.75	—	—	4.00	—	2.00	14.00	—	—	—
MAXITE	T8	.75	—	—	4.00	—	2.00	14.00	—	5.00	—
CARVITE	T9	1.20	—	—	4.00	—	4.00	18.00	—	—	—
	T15	1.50	—	—	4.00	—	5.00	12.00	—	5.00	—

Fourth of a Series of Six Charts Covering A.I.S.I. Tool Steel Type Classifications

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TOOL COLUMBIA STEELS

COLUMBIA TOOL STEELS

HIGH SPEED STEELS: Molite — Molite Smoothcut — Molite #3 DIE STEELS: Superdie — Atmodie — Atmodie Smoothcut — E-Z-Die Smoothcut — Oildie — Exl-Die — Framdie HOT WORK STEELS: Clarite HW — Formite No. 3 — Formite No. 2 — Molite HW10 — Vanadium-Firedie — Alcodie — Firedie SHOCK RESISTING STEELS: Buster Alloy — CEC Smoothcut CARBON TOOL STEELS: Columbia Special — Vanadium Extra — Waterdie Extra — Columbia Extra — Columbia Extra Headerdie — Vanadium Standard — Waterdie Standard — Columbia Standard — Columbia Electrex

Inclusions . . .

and inclusion particles as an undissolved residue. Final separation of carbide particles from inclusions may be accomplished by chlorination and volatilization under vacuum.

Because of certain unsatisfactory characteristics of existing methods the authors developed a new type of electrolytic cell to meet the following requirements.

1. Uniform dissolution of the part.
2. Accessibility of the specimen for removal of loosely adherent particles.
3. Suitable arrangement for collection of particles not adhering to the specimen.
4. Good visibility of the specimen.
5. Provision of a protective atmosphere in the cell.
6. Possible utilization of a variety of electrolytes.
7. Provision of continuous recirculation or renewal of the electrolyte.
8. Provision for measurement and the control of pH of the electrolyte.
9. Ease of operation.

In the newly designed cell the cathode consists of a platinum wire coil surrounding the anode or specimen. This arrangement provides for uniform current density and more uniform dissolution of the specimen. During electrolysis the isolated particles, as they separate from the anode, are collected on a filter or in a settling reservoir while the electrolyte is constantly circulated through the apparatus. Anode and cathode compartments are separated by a cellophane diaphragm which provides suitable conductivity when immersed in the aqueous electrolyte. If it is desired to use different solutions in the anode and cathode compartments the arrangement of the cellophane diaphragm can be appropriately altered. A glass cooling or heating coil maintains desired temperatures during the electrolysis. A protective atmosphere can be introduced into either the upper or the lower part of the cell, serving in the latter case as a means of agitation.

When weak non-complex-forming acids are used, pH control is frequently desirable. The pH is measured by a potentiometer connected to electrodes inserted into the cell, and a burette is provided for acid or alkaline additions as needed to control the pH. W. W. AUSTIN

YOUNG BROTHERS OVENS

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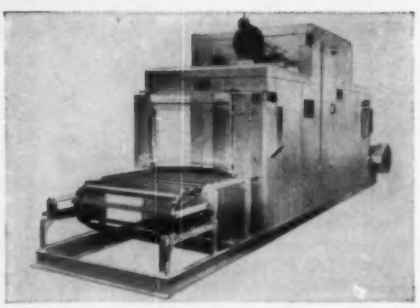

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Tungsten and Titanium Steels Containing Boron

Digest of "Properties of Some Tungsten and Titanium Steels Containing Boron", by A. Banerjee, D. K. Sood and P. Mehta, *Transactions*, Indian Institute of Metals, Vol. 9, 1955-56, p. 143-160.

MOST of the voluminous literature on boron steels relates to the effect of boron on steels used in the heat treated condition. There is little information concerning its effect on low-carbon low-alloy steels in the hot rolled or normalized condition. This paper describes the properties of low-carbon tungsten and titanium steels containing boron and points out their close similarity to low-carbon molybdenum steels.

ALLOY CONSTRUCTIONAL STEELS

Five sections with numerous illustrations, graphs, and charts. Well indexed both from a standpoint of subject matter and author references. A truly valuable reference work. H. J. French, F. L. LaQue—300 pages—6x9—red cloth—illustrated—$4.50. *Clip and send to Technical and Engineering Book Information Service, 7301 Euclid Avenue, Cleveland 3, Ohio.*

Tool Steel Topics

BETHLEHEM STEEL COMPANY, BETHLEHEM, PA.

Hundreds of red-hot wrenches per hour formed and broached with 57 HW

Forming and broaching twelve-point openings in box wrenches from red-hot alloy steel bars is a job that calls for a hot-work tool steel having a high red-hardness . . . good resistance to abrasion . . . and the ability to take shock.

Our 57 HW grade meets these tough requirements—and then some—at P & C Tool Co., Milwaukie, Oregon. Hardened to Rockwell C-50, the die turns out wrenches from rounds of special alloy steel, similar to 4140 grade. After producing approximately 3500 wrenches, the punches and dies are polished with an emery roll, putting them in good shape for some more of the same rugged service.

57 HW is our 9 pct tungsten type of hot-work tool steel. Hardened in air, it has both high red-hardness and high abrasive-resistance. Moreover, it offers good resistance to heat-checking, and more than holds its own in resisting shock.

Typical Analysis

Carbon 0.35	Tungsten 9.35
Chromium 3.25	Vanadium 0.50

57 HW is ideal for a variety of hot-work applications—everything from hot headers to spike cutters, from punch-and-die inserts to nut piercers. Why not let a trial run convince you? Your Bethlehem tool steel distributor is awaiting your call.

BETHLEHEM TOOL STEEL ENGINEER SAYS:

Take a Good Look At Your Grinding Marks

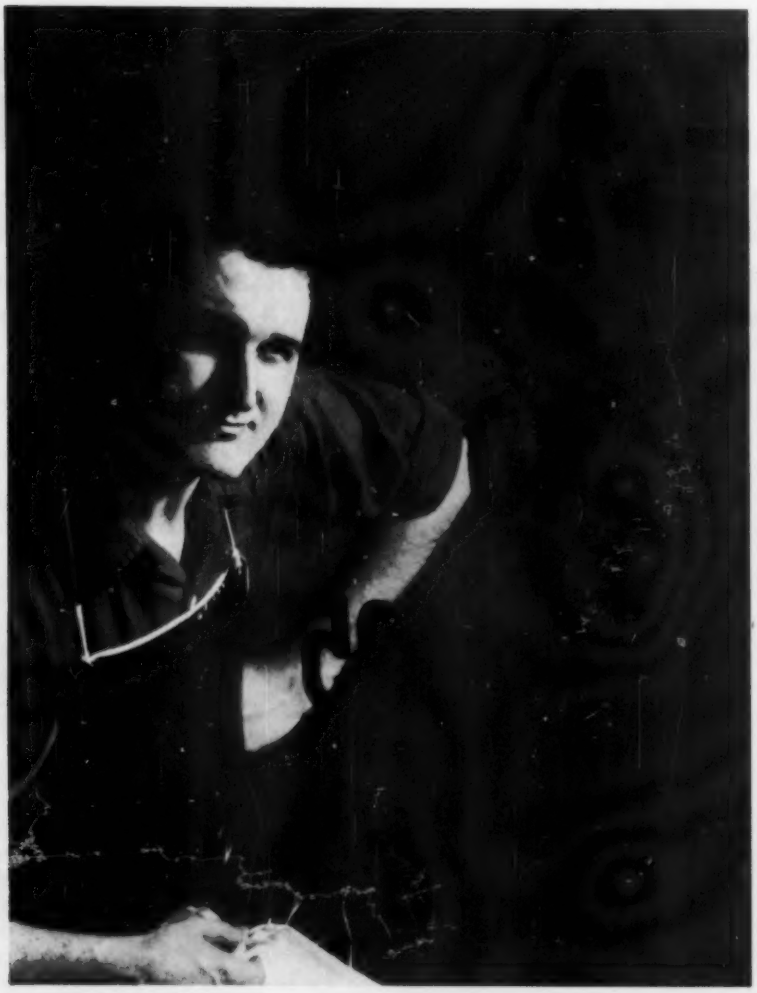
Some people are surprised to learn that grinding marks often play a big part in determining tool life. This is especially true with deep-hardening dies and punches that have a moving contact with metals under high pressures. Although the surface finish of a ground tool may appear smooth, it actually has a saw-tooth contour. Material moving in the same direction as the grinding marks shows less tendency to "pick-up" or adhere, than material which travels across the grinding marks.

This "pick-up" of material is not desirable on such tools as drawing dies. Here it is advantageous to grind in the same direction as the material is to move. On some types of tools this kind of grinding is difficult, but because of the longer tool life obtained, the effort is worthwhile.

Punches which have been ground longitudinally outlast those which have been ground circumferentially, though the latter is by far the most common method. Here, too, longitudinal grinding pays off, even though it may be inconvenient.

It's well to give serious thought to the direction of grinding on tools. It can make a big difference in getting the best possible tool life.

It's just off the press—a completely new two-color booklet on Bearcat tool steel. The booklet is profusely illustrated, and explains fully why Bearcat is such an outstanding grade for a wide variety of shock applications. If you would like to have a copy for reference, write to Publications Dept., Bethlehem Steel Company, Bethlehem, Pa. Ask for Booklet 458.



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D4 – A safety film with contrasty emulsion and light blue base . . . for use without intensifying screens or with metal screens.
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Boron Steels . . .

These steels, developed primarily to provide weight-saving structural materials, used alloy additions to increase strength properties without sacrificing ductility. In the present investigation, it was desired to compare the properties of such steels containing boron with those of the regular low-carbon low-alloy structural steels that do not contain boron.

Preparation of Heats. Experimental heats, with 0.003 to 0.005% boron, were prepared in a 20-lb. basic-lined high-frequency induction furnace and cast into 2 × 3 × 8-in. hot-topped molds. The ingots were forged into ¾-in. square bars or ½-in. thick plate for testing. Compositions chosen made it possible to compare the effect on mechanical properties (determined after normalizing at 1690° F.) of increasing amounts of molybdenum, tungsten and titanium in the presence of boron.

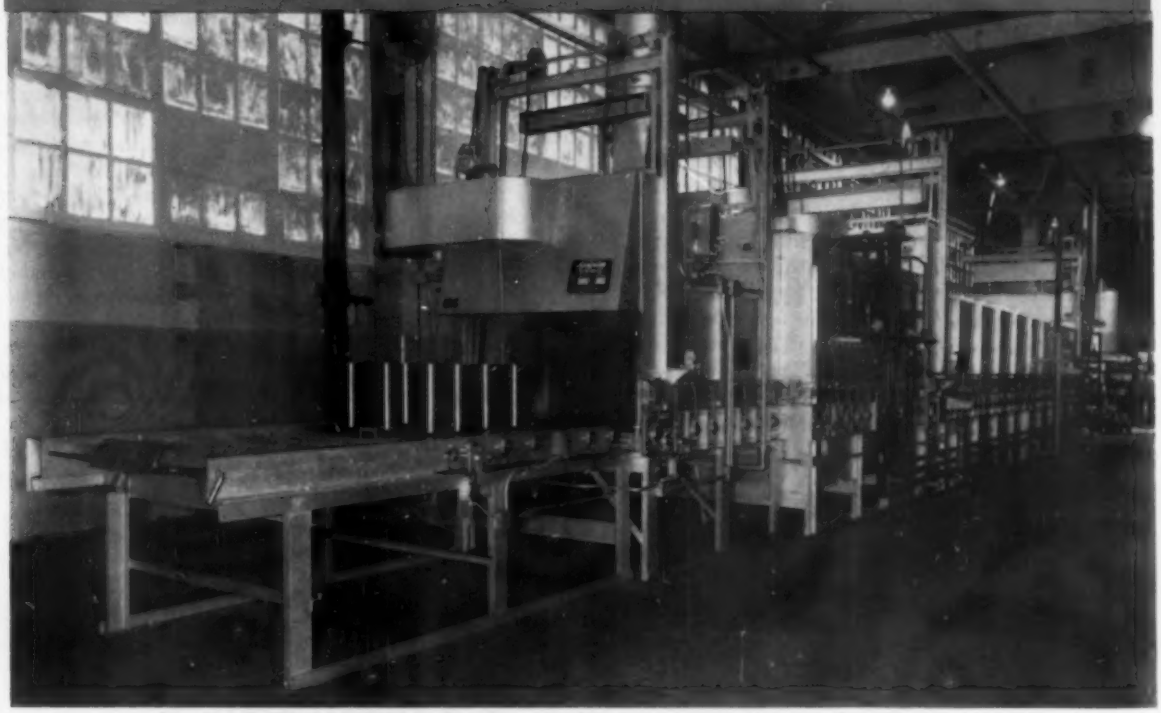
Mechanical Properties. Increasing the molybdenum content from 0.40 to 0.60% of 0.12% C steels with 0.005% B raised the tensile strength by 50% without significantly lowering the ductility. However, impact properties dropped sharply. With over 0.60% Mo, the yield ratio tended to drop with increasing molybdenum content even though a tensile strength of 80,000 psi. was maintained. Since neither boron nor molybdenum alone had the same effect on mechanical properties, the high strength was attributed to their combined effect.

In a parallel study of the influence of tungsten (other variables unchanged), an ultimate tensile strength of 80,000 psi. was reached at 1.4% W as compared to 0.6% Mo. The relative proportions of tungsten and molybdenum needed for the same level of tensile strength is on the same order of magnitude as previously reported by Bain and Gensamer for the ferrite strengthening effects of these two elements.

The effect of increasing titanium content on the mechanical properties of a low-carbon steel containing 0.005% B was also studied. With conventional normalizing at 1690° F., increasing the titanium content to 0.40% Ti had no marked effect on

(*Continued on p.* 186)

Another BIG ONE by Sunbeam STEWART



HEAT-TREATING JET ENGINE PARTS

A wide variety of J57 Turbo-jet aircraft engine parts are being heat treated in four large Sunbeam-Stewart Roller-Hearth furnaces at the world's largest aircraft engine plant in Chicago. Built for Ford Motor Company, Aircraft Engine Division, the furnaces feature four zones of temperature control. Each furnace has overall dimensions of 87 feet in length by 10 feet in width by 15 feet in height. The continuous roller chain drive provides for a speed range of 6 feet per hour minimum to 24 feet per hour maximum. Speed-up drives move work loads through the zone doors quickly. Work is conveyed through the furnace by power-driven alloy rollers which may be removed without shut-down. The roller bearings are water cooled and automatically lubricated. Every precaution has been taken to minimize down time.

Sunbeam Stewart roller-hearth furnaces are widely used for applications requiring continuous high production. They are readily adaptable to the automatic handling of work and to special cycles for heating and cooling.

Whether your requirements call for the installation of a "big one" like the roller-hearth furnace shown above or a complete heat treating department or production line, Sunbeam can handle the job. See Sunbeam first.

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Sunbeam CORPORATION (INDUSTRIAL FURNACE DIVISION)

Dept. 108, 4433 West Ogden, Chicago 23, Illinois

Boron Steels . . .

strength properties. When normalized at 2010° F. significant increases (40 to 50%) in the yield strength and ultimate tensile strength occurred. The effect of high normalizing temperature on tensile properties of titanium steels is in agreement with earlier studies.

Precipitation Hardening. A study of the binary diagrams of iron alloyed with molybdenum, titantium, tungsten and boron reveals that all of these elements exhibit decreasing solid solubility with decreasing temperature, a well-known requisite for precipitation hardening. Boron probably forms a substitutional solid solution in ferrite but an interstitial solid solution in gamma iron. As a substitutional element, boron promotes a strength increase in ferrite similar to most of the usual alloying elements in steel. Since boron can also induce precipitation hardening in iron, the total strengthening effect is probably a combination of the substitutional effect and a precipitation hardening effect. Molybdenum, tungsten and titanium also produce precipitation hardening alloys with iron. It is therefore reasonable to assume that the precipitation effect of these alloying elements is further accentuated by boron.

On the basis of these assumptions, experiments were made to determine if precipitation effects occurred in the low-alloy high-strength boron steels containing molybdenum. Boron steel specimens with molybdenum ranging from 0.08 to 1.46% were homogenized at 1470, 1650, and 1830° F. for 1 hr., aged for 3 hr. from 212 to 1470° F. and tested for hardness. No precipitation hardening was observed for the boron steels with 0.08 and 0.17% Mo. It appeared at 0.34% Mo, was most pronounced at 0.40% Mo, dropped at 1.0% Mo, and disappeared at 1.46% Mo content. Microscopic examination of the specimen with 0.45% Mo showed that the aging treatment induced a finely divided precipitant clearly visible in the ferrite grains.

Welding. The low-carbon boron steels with molybdenum, tungsten and titanium are readily weldable. Tests performed on the experimental steels showed that tungsten-boron and titanium-boron steels compare favorably in weldability and in cracking to the molybdenum-boron steels.

Effects of Additions on Ferrite. Gensamer has shown that the effect of carbon in steel may be visualized as a reinforcement resulting from the interruption of the path of applied stress through soft ferrite by the presence of hard cementite particles. This strengthening effect, according to him, far outweighs that produced by the introduction of alloying elements into solid solution in ferrites. In the absence of carbon, however, molybdenum, tungsten and titanium dissolve in and strengthen the ferrite by expansion of the lattice parameter. These elements also retard the austenite-ferrite transformation and produce a fine pearlitic structure at relatively slow rates of cooling.

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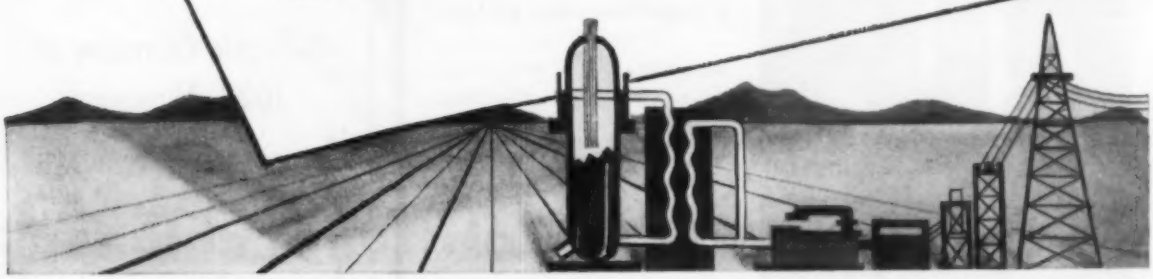

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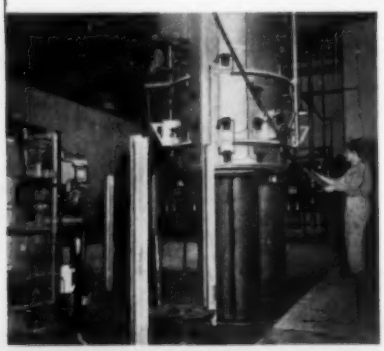

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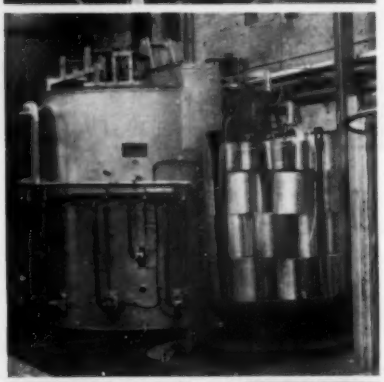

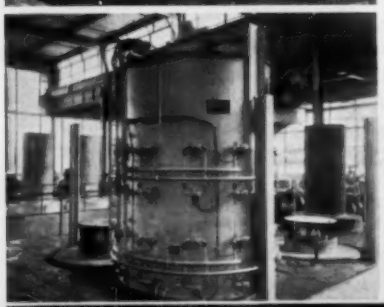

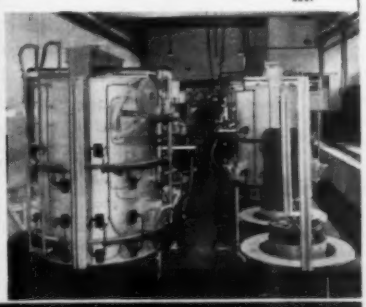

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Boron Steels . . .

molybdenum which, in turn, is about one-half as effective as titanium. Because of the similarity in the effects of titanium, molybdenum, and tungsten on ferrite, similar properties were obtained with the tungsten and titanium-boron steels; however, the cost factor favors molybdenum-boron steels. W. W. AUSTIN

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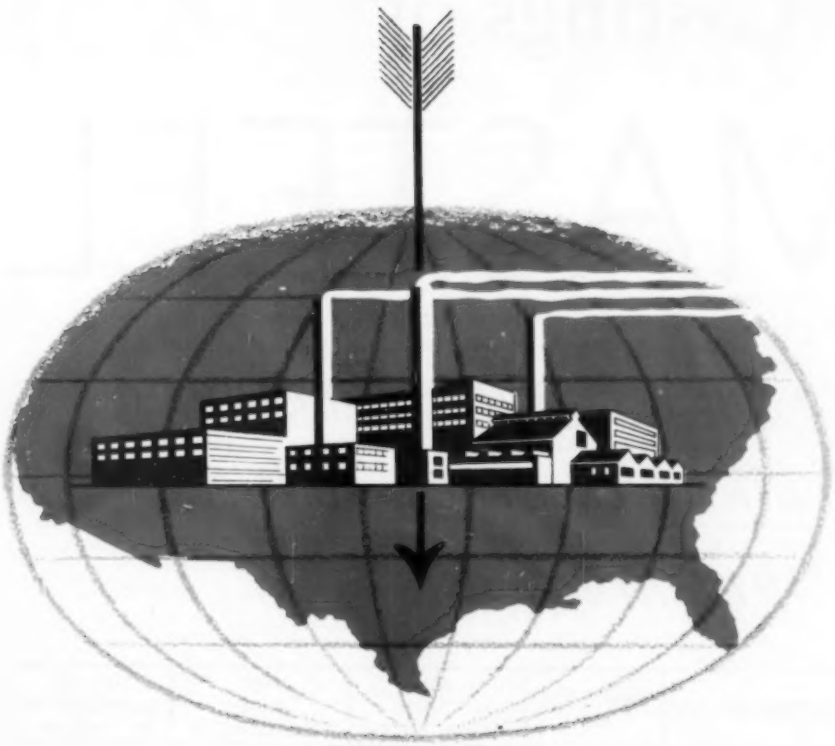
Galvanic Corrosion of 2024 Aluminum

Digest of "Galvanic Corrosion of Aluminum", by F. Pearlstein, *Metal Finishing*, Vol. 54, April 1956, p. 52-57.

THE AUTHOR studied the corrosion of 2024-T 3 aluminum panels exposed to salt spray. One set of panels was left bare, another set was anodized in sulphuric acid and sealed in a sodium dichromate solution, while the third set was anodized and left unsealed. Discs of various materials were connected to the aluminum panels in order to make galvanic couples. The discs were made of bare copper, bare steel, cadmium-plated copper, tin-plated copper, cadmium-plated steel, nickel-plated steel, stainless steel and titanium. Polystyrene discs were also used for corrosion control.

The panels were examined after 24, 72, 168 and 336 hr.-exposures to salt spray. They were removed after 600 hr. exposure and stripped in a solution containing phosphoric and chromic acids. The panels were then brushed with scouring powder and dipped in acetone. For each panel the loss of weight due to galvanic corrosion was determined.

(*Continued on p.* 192)



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ARMASTEEL GM 86M	Recommended for less highly stressed parts. Replaces steel parts in 1020-1035 S.A.E. range.	163-207	70,000	48,000	4.0
ARMASTEEL GM 85M	Recommended for moderate strength plus adaptability to selective hardening. Replaces parts in 1035-1050 S.A.E. range.	197-241	80,000	60,000	3.0
ARMASTEEL GM 84M	Recommended for high degree of strength. Replaces heat-treated parts in 1040-1050 S.A.E. range.	241-269	100,000	80,000	2.0
ARMASTEEL GM 88M	High resistance to wear and high yield strength, yet retains machinability. Requires no heat-treating and possesses same strength and wear characteristics as alloy steel forgings.	269-302	105,000	85,000	2.0

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ARMASTEEL, a pearlitic malleable iron, possesses the same strength and performance characteristics usually associated with plain carbon steel. In addition, ARMASTEEL contains excellent bearing properties, has high yield strength, good damping capacity, maximum rigidity and excellent fatigue life. Accurate control of heat-treating operations in the manufacture of ARMASTEEL produces a fine, uniform grain structure and provides excellent finishing qualities.

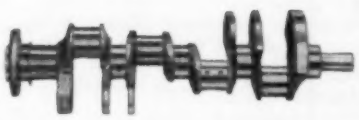
Four different types of ARMASTEEL can be cast to your specifications. One of the four (GM 84M, GM 85M, GM 86M or GM 88M) will have the physical properties to best meet the requirements of your application. For example, ARMASTEEL castings are being successfully used in the automotive, appliance and implement fields for such parts as gears, pistons, crankshafts, rocker arms and universal joint yokes, all of which utilize to best advantage the outstanding characteristics of ARMASTEEL.

Some of these applications are shown in the table. Look them over carefully; you may find that these characteristics and advantages of ARMASTEEL can help reduce your costs . . . increase your production . . . and improve the performance of your products.

Typical ARMASTEEL castings

Because of the greater physical properties of GM 86M ARMASTEEL, it was possible to redesign this anchor plate as shown and effect a weight reduction from 2.26# per piece to 1.44# per piece.

GM 86M ARMASTEEL provides the ideal casting for this automobile differential case because of its high strength, minimum deflection and good damping qualities which contribute to quietness of operation. Note the as-cast internal cavity and the web-formed webs.



GM 85M ARMASTEEL provides a crankshaft with more desirable machining characteristics than a forged crankshaft of SAE 1045 steel. Improves machining of journals and reduces chucking stock. Use of GM 85M ARMASTEEL made possible the redesign of the crankshaft with a resulting 3.5# weight reduction and a lower material cost.

By converting to GM 85M ARMASTEEL, drilling and boring operations were eliminated on this crankshaft sprocket. Stock in rough part was reduced from 1.93# in forging to 1.00# in casting. Customer realized reduced piece price with GM 85M ARMASTEEL.

GM 84M ARMASTEEL was specified for this socket plate journal because its microstructure makes it more easily machined than steel with the same physical properties. It has better bearing and wear resistance qualities . . . less distortion during machining . . . and does not require heat treatment. Weight of part in rough is less than comparable steel forging.

Crankshaft for newly designed small gasoline engine. GM 84M ARMASTEEL specified because of outstanding success in similar engines. Less stock removal and better machinability are advantages over forged crankshaft.

This planet gear carrier was formerly forged from SAE 1141 steel, which required a heat treatment after rough machining and broaching operations. By converting to GM 88M ARMASTEEL, heat treatment was eliminated and the weight of the rough part was reduced.

By converting to GM 88M ARMASTEEL for this universal joint yoke, hole thru hub could be cast in . . . eliminating a drilling operation and reducing weight of part approximately 30%. GM 88M ARMASTEEL part has lower piece price than forging formerly used.

85

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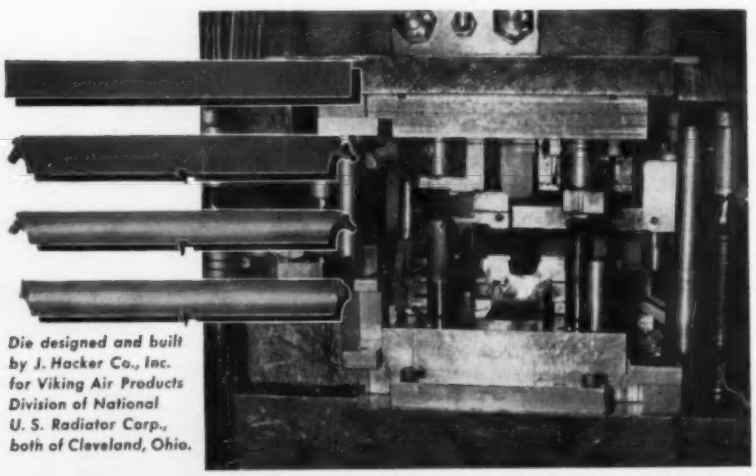
Corrosion . . .

There was little difference in the appearance of the specimens between 24 and 72 hr. in salt spray. The bare panels were covered with white corrosion products, the anodized-sealed panels were unaffected and the anodized-unsealed panels showed light corrosion. All cadmium-plated discs showed signs of corrosion after 168 hr. in salt spray. After 600 hr. exposure, all of the cadmium-plated discs on bare aluminum were corroded to the base metal, the average area devoid of cadmium being about 40% of the disc area. In the cadmium-plated discs attached to anodized panels, the average exposed area was about 3%. Where copper discs were used, the anodized-sealed panels were most severely corroded at the junction, the bare panels showed extensive rather than intensive corrosion, while the anodized-unsealed panels displayed spotty corrosion.

The weight losses of aluminum due to galvanic corrosion were determined after 600 hr. exposure. Results are tabulated for the three types of panels in contact with the various kinds of discs. Panels in contact with bare copper discs were the most severely corroded. Steel discs also caused severe corrosion of aluminum. Nickel, titanium and stainless steel caused aluminum to corrode, except where titanium was coupled to an anodized-sealed panel.

This experiment thus shows that copper and steel are highly cathodic, tin is slightly cathodic, while cadmium is slightly anodic to 2024 aluminum. Consequently, tin or cadmium plate can be used in contact with anodized 2024 aluminum with little or no adverse effect.

A. COUTURE



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Iron by Direct Reduction

Digest of "New U.S. Developments in Direct Reduction", by A. Hegarty, *Iron & Steel*, October 1957, p. 483-485.

THREE PROCESSES have been attracting attention, varying principally in the temperature and pressures existing in the ore reduction chambers. The so-called H-iron process is described in this issue of *Metal Progress* (p. 92); it was devised by Hydrocarbon Research Corp. with Bethlehem Steel Corp. and Alan Wood Steel Co. It reduces magnetite with dry hydrogen at low temperature, 900° F. (to prevent agglomeration of reduced particles) and high pressure, 400 psi. (to speed the reaction).

The U.S. Steel Corp. has a pilot plant at South Chicago, but no official announcement has been made of the progress at this point. From patent applications and unofficial sources, it is believed that somewhat

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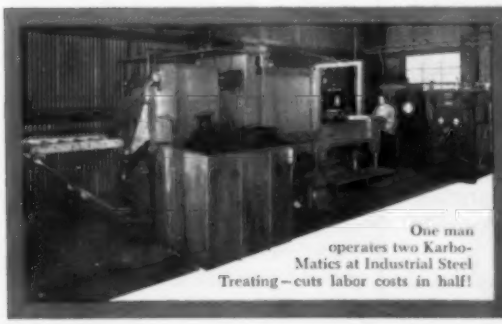

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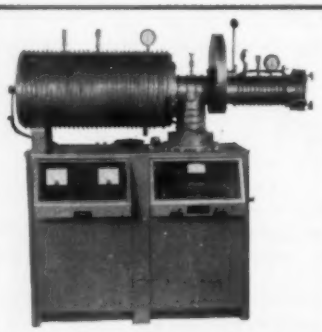

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Direct Reduction . . .

higher temperatures (1300° F.) and moderate pressures (60 psi.) are used in two fluid bed reactors, the first reducing the ore to what is essentially FeO and the second completing the reduction. The gas is a dry mixture of CO and H_2 formed from natural gas and steam.

The third process, which apparently is still in small pilot plant experimentation, utilizes a multiple fluid bed for reducing the ore; heat is generated at its base by partial combustion of natural gas. Air is preheated to 1550° F. and the natural gas to 650° F. Some of the resulting CO-H_2-N_2 mixture is burned separately in an ore preheater, bringing the ore up to 1550° F. Preheated ore passes by gravity into the reducing reactor consisting of three fluidized bed stages, countercurrent to the CO-H_2-N_2 gas. Reduced iron then goes to a cooler and a briquetting press. Top gas is similar to blast furnace gas, having a calorific value of 120 Btu. per cu. ft., and it is cleaned and sent to a power plant or to heating furnaces. This process was adopted by Warren K. Lewis from his very successful equipment for catalytic cracking of petroleum at Esso gasoline refineries in conjunction with Arthur D. Little. The Esso-Little reduction process thus utilizes rapid reaction at high temperature and normal pressures in multiple stages of reduction and, instead of recirculating the gas, uses the spent gas for its calorific power in associated operations.

E. E. THUM

Molybdenum at High Temperatures

Digest of "Protecting Molybdenum at High Temperatures", by J. J. Harwood, *Materials in Design Engineering*, Vol. 44, December 1956, p. 84-89.

THE MAJOR OBSTACLE to wider utilization of molybdenum as a high-temperature high-strength material is its complete lack of resistance to oxidation at temperatures above 1000° F. The formation of the highly volatile molybdenum trioxide prevents the formation of a protective oxide. At about 1415° F.,

(*Continued on p. 196*)

Turbine spiral case being fabricated of USS "T-1" Steel in the shop of the S. Morgan Smith Co., York, Pa. Plates ranged in thickness from ½" to 1 1/16".

Taming the mighty Snake River with turbine spiral cases of USS "T-1" Steel

Stronger steel reduces weight . . . cuts costs

Four of these huge spiral cases are being built for the Idaho Power Commission for use in the Brownlee Dam on the Snake River near Robinette, Oregon. They are designed for a 250-foot head of water. The inlet is 18 feet in diameter and each turbine will generate 144,000 horsepower at a speed of 128.6 rpm. Water will flow through the cases at a rate of 5,640 cubic feet per second.

Because of the fierce pressure, it was obvious that a strong steel was required. USS "T-1"* Steel was selected because it has a minimum yield strength of 90,000 psi. What's more, it can be fabricated, is readily weldable and has high resistance to impact abrasion.

Cost savings. By using USS "T-1" Steel, there will be substantially less shipping weight across the country and less weld time and weld metal, both in the shop and on the job site. Had carbon steel been specified, double thicknesses would have been required.

Fabricating operations. Projection of the dimensional outline on the plates was done with Lumitrace. Plates were cut to size by flame-cutting and rolled cold to shape. Some parts were finish welded, others were tack welded and assembled. The spiral case was then disassembled and shipped. Finish welding of segments is to be done at the dam site.

This job points up the economies possible with the use of USS "T-1" Steel. Why not use it for your own equipment? Write for our "T-1" book containing complete information. United States Steel Corporation, Room 2801, 525 William Penn Place, Pittsburgh 30, Pa.

Remember that we also make USS COR-TEN*, USS TRI-TEN* and USS MAN-TEN* Steels . . . widely used in power generation equipment.

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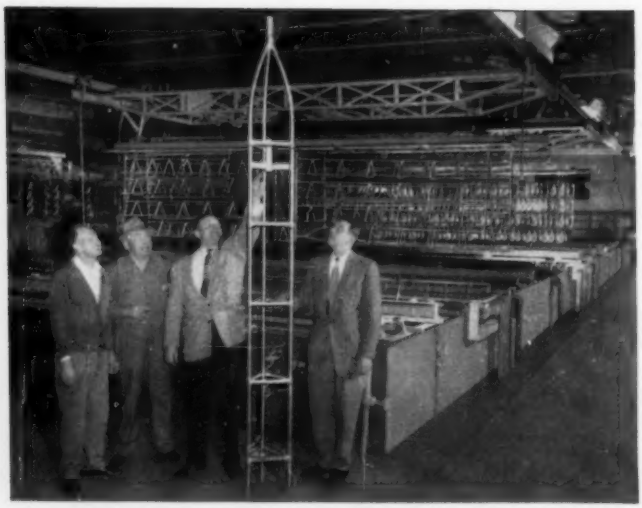

Messrs. Cliff Stern and Nick Servatius of Modern Plating Corp., Freeport, Illinois; Ed Wild, Ardco, Inc., and Dick Servatius, Modern Plating Corp., are enthused over the results obtained with ROHCO 503 ZINC BRIGHTENER.

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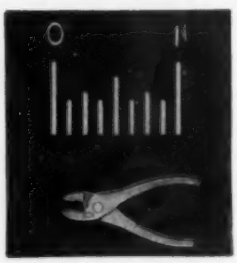

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Molybdenum . . .

the evaporation rate of the trioxide is equal to its rate of formation. At 1800° F. in slowly flowing air, the surface of molybdenum recedes at a rate of 0.02 to 0.05 in. per hr. as compared with a rate of 0.00073 in. per hr. for a satisfactory iron-chromium-nickel alloy. In these conditions, it appears that molybdenum is useless for high-temperature use unless some form of surface protection is developed.

One approach to this problem is the development of alloys capable of forming resistant protective oxides (as obtained in other systems). This approach failed: the best alloys of molybdenum with chromium and titanium, or chromium and nickel, had an oxidation rate only 100 times lower than unalloyed molybdenum. The other alternative is the use of protective coatings such as metal claddings, ceramic and other refractory compounds. This paper reviews the results of these methods of protection.

To be successful, a coating must have adequate resistance to oxidation, thermal shock, impact and erosion and should be able to withstand a minimum amount of creep strain without fracturing.

Electrodeposited coatings of nickel provide up to 500 hr. of life at 1650° F. while those of chromium afford the same protection at 1800° F. while in thicknesses of 3 to 4 mils. Drawbacks of the nickel electrodeposits are poor adherence to substrate, poor resistance to thermal cycling, rapid diffusion of molybdenum through nickel at 1800° F., spalling characteristic of nickel oxide and nickel molybdate, and many others. Tests on chromium deposits were not reproducible, the useful life varying from 5 to 500 hr.

Chromium-nickel electroplates, on the contrary, show great promise for applications up to 2000° F. A 1-mil layer of chromium is first deposited, then nickel in thickness up to 7 or 8 mils. The surface preparation and the whole process must be carried out with extreme care. With this type of coating, thousands of hours of protection may be achieved up to 1700° F.

Claddings of nickel and nickel-chromium alloys show great promise

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Molybdenum . . .

for molybdenum sheets and simple shapes. Claddings of Inconel afford good protection for 100 hr. at 2000° F. Nickel-rich claddings give protection even in the presence of local defects and cracks, probably because of the formation of nickel molybdate. Design strength of such composites are based on the strength of the core alone.

Sprayed coatings of aluminum-chromium-silicon alloys and of nickel-boron alloys are very effective. The Al-Cr-Si alloys are superior to all others tested from the point of view of thermal shock and cycling tests. The Ni-B-Si and Ni-B-Si-Cr alloys withstand the ballistic impact of steel shot at 330 ft. per sec. without exhibiting any deterioration in oxidation resistance at 1800° F.

Diffusion coatings of silicon, titanium and zirconium are formed by a pack cementation process and have so far shown most promising protection except in thermal cycling.

Molybdenum disilicide coatings produced by vapor deposition of silicon or pack coating in silicon powder show best oxidation resistance. Coatings of 3 to 4 mils have given up to 6000 hr. of service at 1500° F. and 50 to 300 hr. at 3000° F. Thermal shock resistance is reasonably good and at high temperatures coated parts can be bent without cracking. Some of the drawbacks are poor impact and fatigue resistance and need for use above the recrystallization temperature.

Ceramic coatings of alumina, magnesia, silica, rutile, zirconia, beryllia and their combinations have been tested. The common approach is to use a combination of refractory oxide and a glass phase to minimize differential expansion between it and the substrate. They have, unfortunately, many disadvantages and are only used for short-time applications or where severe thermal shock, high stresses or impact conditions are not involved. In multilayer systems they provide an erosion resistant outer layer on an oxidation resistant ductile-base coat.

Surface barrier layers of stable oxides produced at the surface of molybdenum alloys also have been studied. Although not considered very attractive, they give a certain protection up to 1800° F., and have the interesting property of self-healing and regeneration when damaged.

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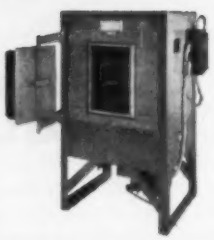
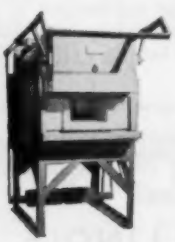


Recirculating Air Draw: box type furnace for controlled heating to 1300° F.—steel tempering, glass annealing, etc. 8 sizes to 24" w. x 15" h. x 48" d.

Bench Type: for tools and small parts—to 2000° F. 14 sizes to 10" w. x 8" h. x 18" d.

Recirculating Ovens: for drying, finishing and industrial processing to 600° F. 5 sizes to 36" w. x 36" d. x 60" h.



High Temperature Box Furnace: for high speed steel treating to 2500° F. 3 sizes to 12" w. x 8" h. x 24" d.

Industrial Box Furnace for general heat treating—to 2000° F. 8 sizes to 24" w. x 18" h. x 48" d.

Catalog and complete information on any of these furnaces will be gladly furnished on request.

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Gas Flushing of Nodular Iron

Digest of "Effect of Gas Flushing on the Consumption of Magnesium in the Production of Nodular Iron", by Wilhelm Patterson, *Giesserei* (German), Vol. 9, April 25, 1957, p. 216-227.

THE MECHANISM of gas flushing is rather complex. In instances where the gas is metallurgically inert with respect to the melt, two phenomena take place simultaneously:

1. Gases dissolved in the liquid metal are removed by diffusion of their ions into the bubbles of the flushing gas. The diffusion reaction

(*Continued on p.* 200)

Production cutting of bar stock on a ***HILL ACME*** *Bar-Billet Shear with auxiliary automatic feed*

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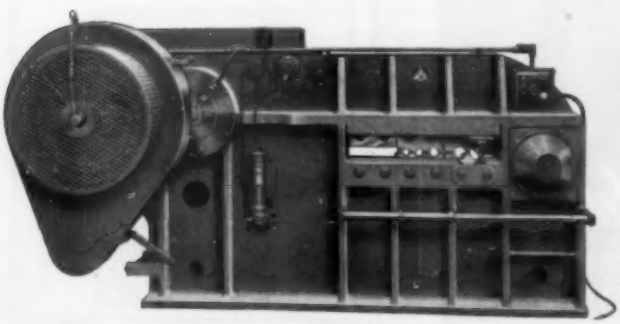

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Gas Flushing . . .

occurs because of a difference between the two partial pressures. The longer the flushing gas remains in contact with the "tramp" gas, the smaller the bubbles become.

2. Small foreign particles, suspended in the melt, rise more rapidly to the surface with gas bubbles attached, because of their increased buoyancy. As the bubbles become smaller and more widely distributed, the process becomes more efficient.

If the flushing gas reacts with certain components of the melt, either liquid or solid compounds form. These compounds will rise to the surface if an excess of flushing medium is present.

Two theories concerning the formation of nodular graphite are preeminent. One postulates that the high surface tension of magnesium-treated cast iron is responsible for changing the shape of graphite; the other suggests that the effect of nuclei of trace elements is decisive in determining the spherulitic shape of graphite particles. In both theories the influence of sulphur and oxygen is dominant.

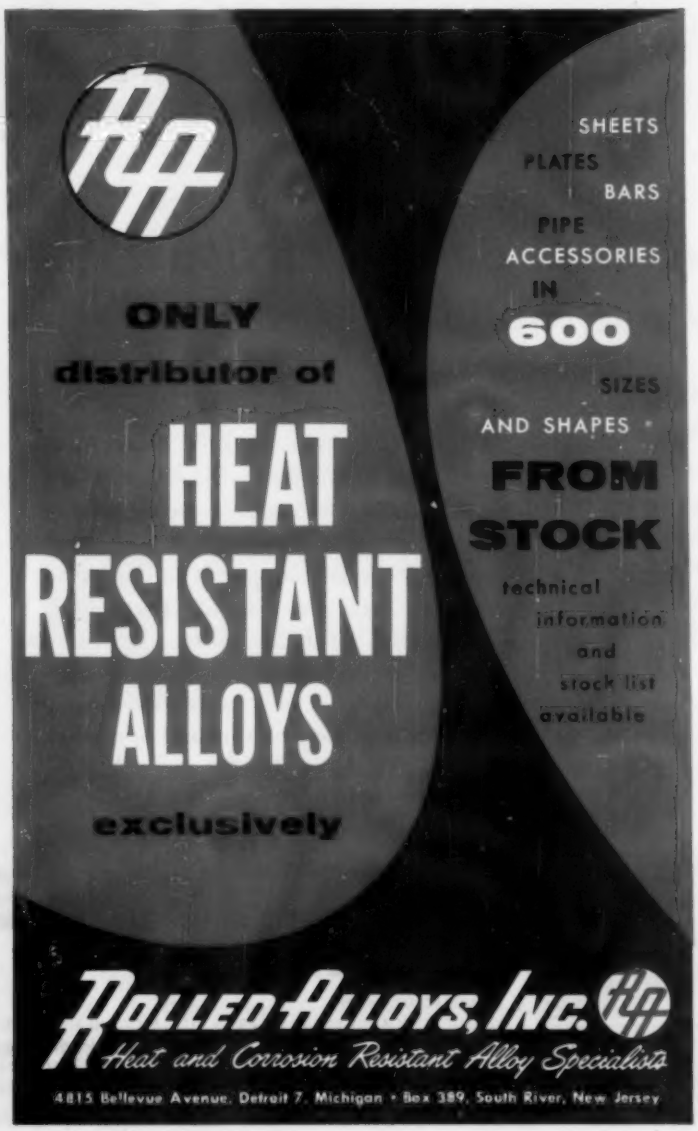
It was reasoned that flushing with gas might remove at least part of the detrimental nuclei and that the effectiveness of magnesium inoculation might be enhanced. Specifically, the following two questions required answers: (*a*) Will flushing make possible the use of smaller amounts of magnesium? (*b*) Can flushing minimize or eliminate the undesirable effects of certain trace elements?

A series of experimental heats were run varying the amount of prior desulphurization and adding predetermined amounts of magnesium. The flushing time was regulated as was the flow rate of the nitrogen bubbles.

It was shown that magnesium desulphurizes as well as deoxidizes, and that small additions of earth alkalis cause an initial decrease in mechanical properties prior to the formation of nodular graphite. Nitrogen acts as a desulphurizing agent only when sulphides are suspended in the melt. These are then floated to the surface by the attached gas bubbles. Flushing with nitrogen either by itself or in combination with soda ash definitely established the fact that the amount of magnesium needed for the formation of nodular graphite is markedly reduced by this procedure.

An investigation of the effect of gas flushing on the influence of trace elements during the formation of nodular graphite showed that a gas treatment improves the response to magnesium inoculation. It was further determined that the flushing agent should be introduced in such a manner that small bubbles rise slowly from many openings throughout the melt.

A new theory concerning the mechanism of growth is also discussed in the article. HANS HEINE



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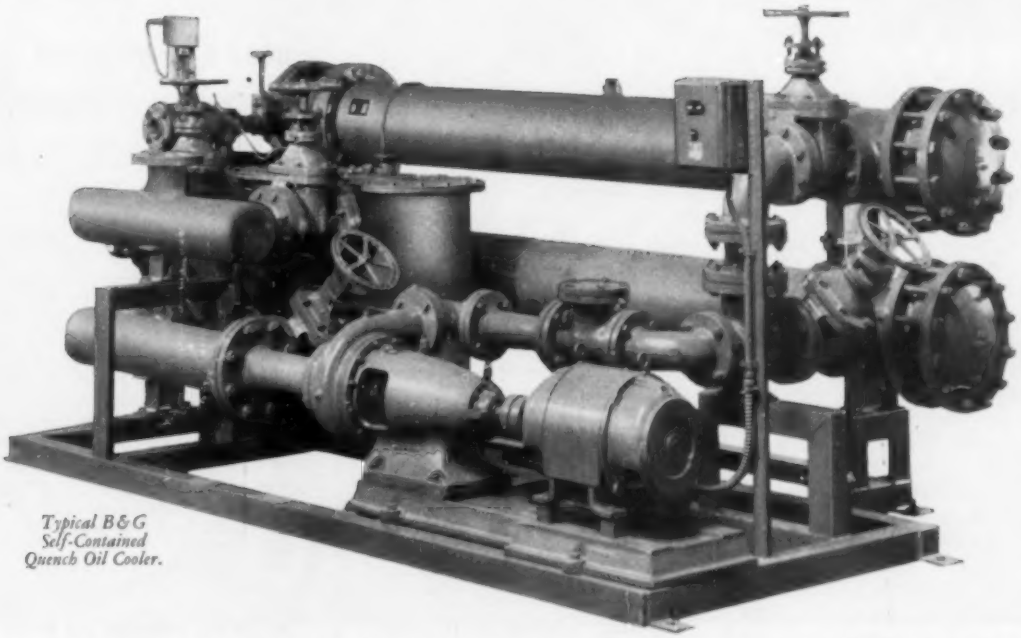

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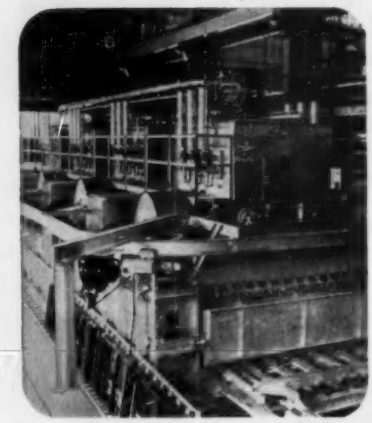

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Leveling Nickel

Digest of "Leveling Nickel", by D. Gardner Foulke, *Metal Finishing*, Vol. 54, October 1956, p. 52-56.

SINCE the first comprehensive account of the leveling phenomenon in 1950, considerable progress has been made. A project has been established at the University of Virginia on micro throwing power which is closely related to the leveling effect. The magnitude of this effect is shown in the following table. Electroformed roughness standards were used as base material.

Rms. of Standard	Rms. With 1-Mil Deposit	Percentage of Leveling
20	1	95
50	9	82
125	70	44
500	390	22

One mil of nickel was deposited from a leveling solution operation under typical conditions (150° F., 72 amp. per sq.ft., pH 2.8) with an acetylenic-type addition agent. The leveling effect is very much less with rough surfaces because the diffusion layer effect is smaller. In such cases a heavier deposit would be required if much leveling were to be obtained.

Two types of addition agents are employed, ethylene cyanhydrin and coumarin. These are coupled with high temperature, relatively high current densities and high chloride values (nickel chloride 12 to 15 oz. per gal.). Air agitation can be used without causing oxidation, and stresses in the deposit can be maintained at near zero or slightly compressive values.

Leveling, whether it is accomplished by elimination of projections or filling of crevices, is a result of a difference in the diffusion layer thickness and is associated with an increase in cathode polarization over the polarization caused by the ordinary brightening agents.

Variables which effect leveling are (*a*) current density – an increase from the optimum will result in a lower rate of leveling, (*b*) bath pH – an increase to 3 or 4 will increase the leveling, (*c*) higher temperatures – they generally increase leveling but the effect may be complex. The effect of agitation on leveling depends on conditions. In

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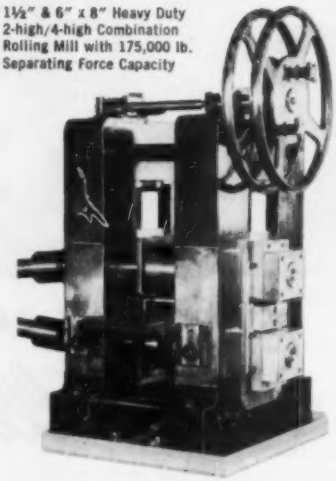

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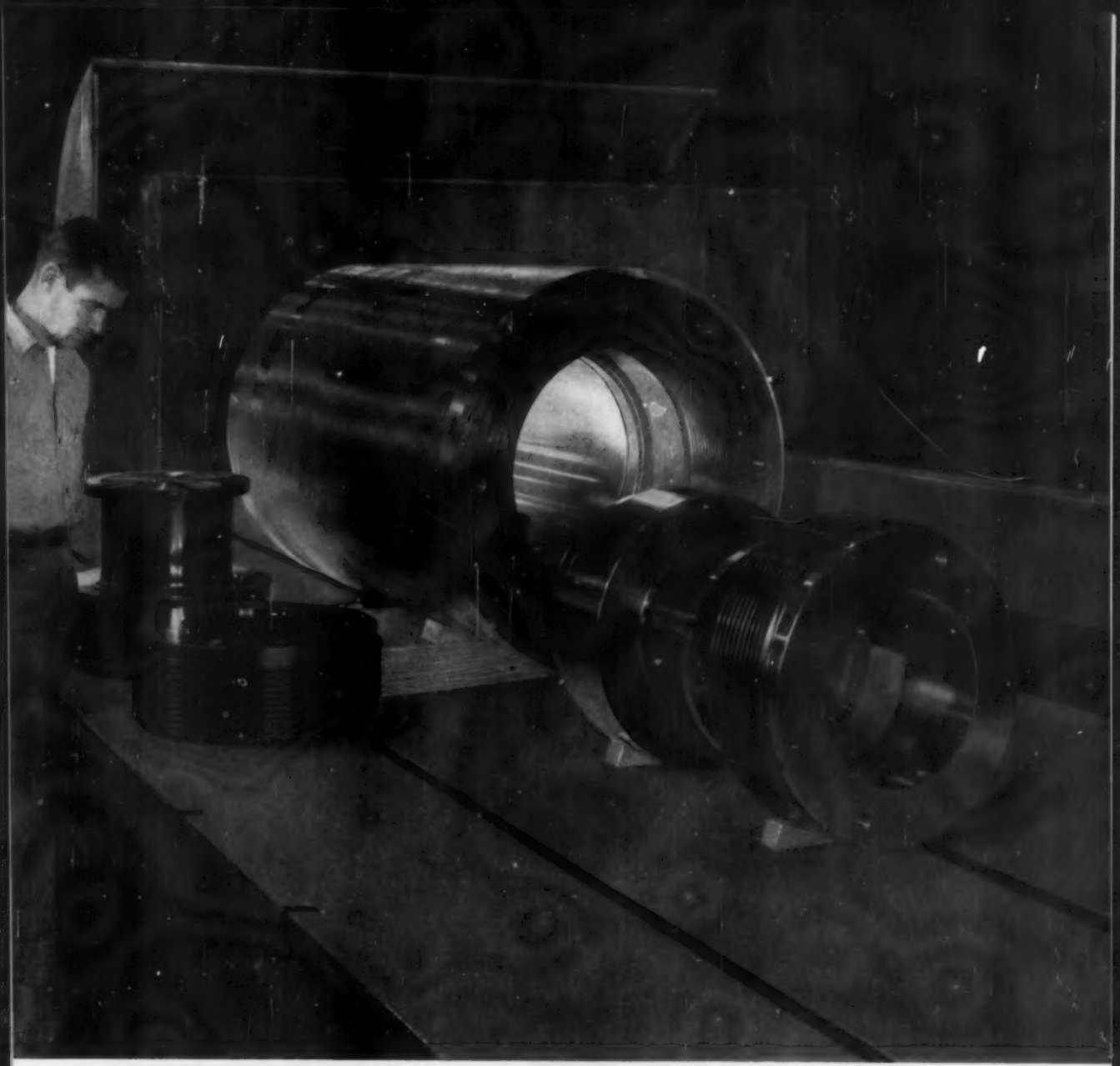

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For more information on "the tough ones," and the machinery that makes them "best"—write for Bulletin NFO 2.

Nickel . . .

nickel baths heavy with acetylenic brighteners, stirring has no effect.

Duplex coatings have been shown to result in better corrosion resistance. For example, a leveling plate of 1 mil total composed of 80% semibright and 20% full-bright nickel gave protection equal to that obtained from 1.2 mil of conventional bright or semibright nickel.

R. L. ANDERSON

Low-Nickel Stainless Steel

Digest of "Production and Fabrication of New A.I.S.I. Types 201 and 202", by G. W. Hinkle, A.S.T.M. *Bulletin*, February 1957, p. 47-50.

THE FAMILIAR 301 and 302 types of stainless steel are being replaced in many applications by low-nickel A.I.S.I. types 201 and 202. In these steels, 5% manganese and 0.25% nitrogen are used to replace about half of the nickel used for austenitic stabilization in types 301 and 302. The new steels, which contain only about 4.5% nickel, are suitable for articles requiring good surface finishes such as cooking utensils, household appliances, automotive and architectural applications. To be economically acceptable, the new steels must not increase fabricating costs. Consequently, the steel producers and their customers are investigating their fabricating characteristics quite extensively.

The high manganese and nitrogen contents of types 201 and 202 result in greater strength at elevated temperatures. This characteristic necessitates some changes in blooming mill practices in order to minimize increases in power consumption. For example, increases in soaking-pit times of about 20%, and slightly higher rolling temperatures, compared to procedures for 301 and 302 steels, are desirable. The net result, for production rates on type 201, and 20% slower blooming-mill processing of type 202 steel. No problems were met in rolling slabs to hot strip.

The manganese-nitrogen stainless steels work harden more rapidly than the higher nickel 301 and 302

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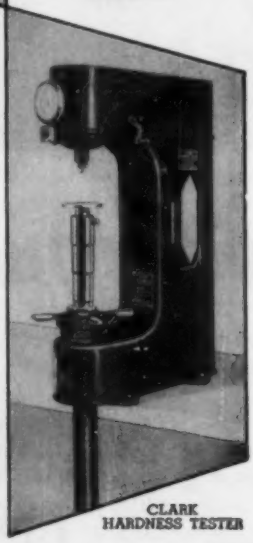

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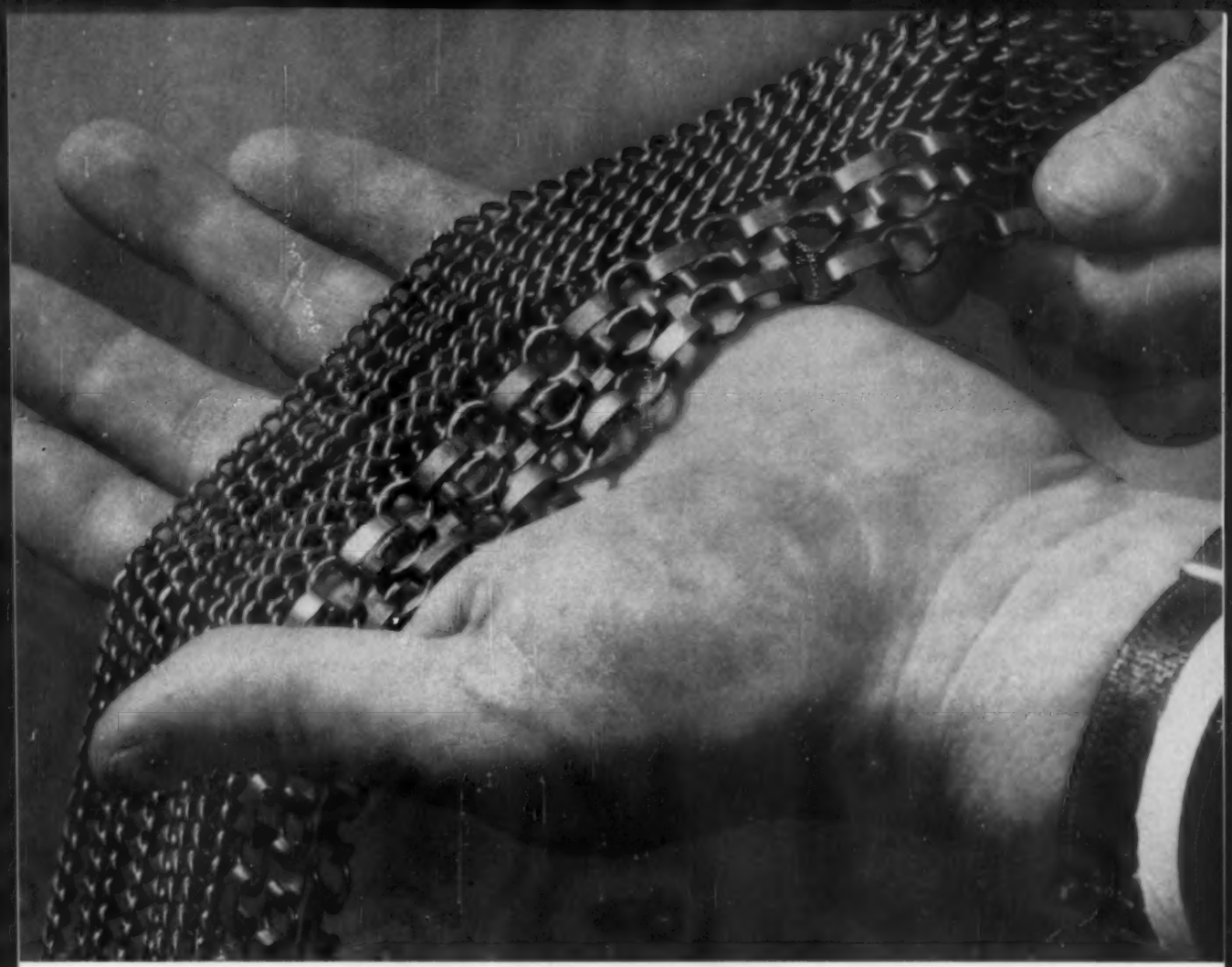

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Here we touch only briefly on a few of the unique Copperply features, but perhaps enough to spark an idea worth exploring. And you'll find that the word "cooperation" has real meaning at National-Standard . . . whether your interest lies in Copperply wire or any of our other products. Try us.

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Stainless Steel . . .

grades. Therefore, about one-fifth more passes are required in cold rolling to produce a particular reduction in gage. Conversely, approximately 10% less cold reduction is required on 201 and 202 steels to meet the requirements of half-hard stainless strip.

The newer steels oxidize more readily above 1600° F. and this necessitates some changes in annealing and pickling procedures. The 201 and 202 steels are normally full annealed by cooling rapidly from 1825° F., instead of 1950° F., to minimize scaling and to insure a good finish. The use of the lower annealing temperature causes some loss of ductility. The acid baths normally used for the older austenite steels are modified by reducing the acid concentrations about 10% and by lowering the bath temperatures about 15° F. Caustic pickling baths have also been used for descaling the 201 and 202 steels.

The tooling and operations used for brake and roll forming 301 and 302 steels were satisfactory experimentally. In production runs on material annealed at lower temperatures, to meet surface finish requirements, some changes in forming radii are necessary to compensate for greater springback.

These steels have been used satisfactorily for production runs on automotive parts and on single-draw tubs and sinks using dies designed for 301 and 302 stainless steel. Slightly larger blanks and hold-down pressures were preferable for the manganese-nitrogen steels. The parts deep drawn from 202 steel usually exhibited higher hardnesses and slightly heavier sections than those made from 302 steel. Grinding, buffing and electrolytic polishing practices used for 302 stainless are normally satisfactory for types 201 and 202. Equivalent surface finishes can be produced and there is little, if any, difference in color or appearance among the steels. Welding procedures and requirements do not have to be changed for 201 and 202 steels. Regular type 304 electrode can be used for joints and repair welds.

Laboratory tests detected no differences in stress cracking tendencies between samples of types 201, 202

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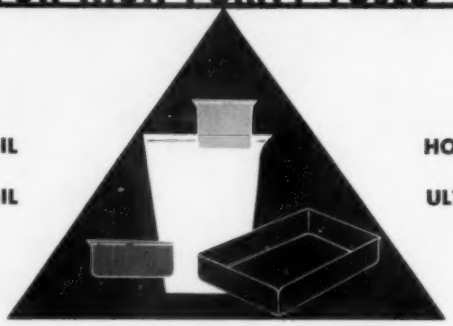

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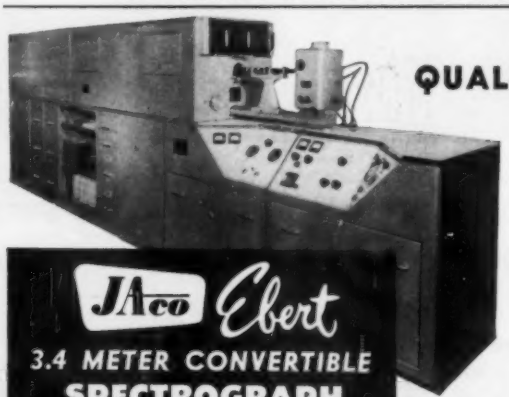

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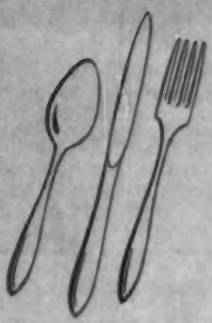

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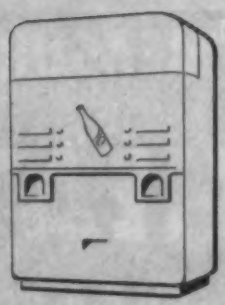
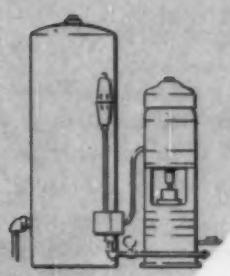


FITTINGS AND VALVES



PUMP SHAFTS
AND VALVES

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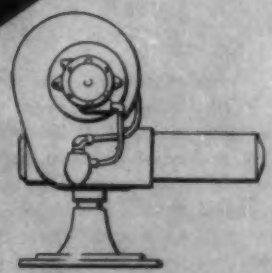

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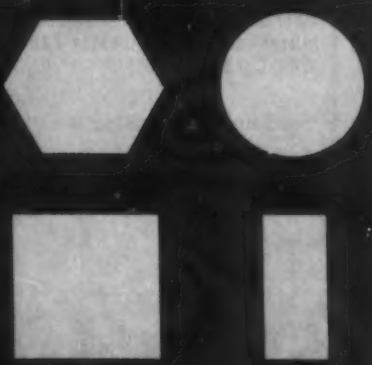

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If you use stainless steel in the manufacture of your products, they will be improved with the excellent quality of J & L Stainless Steel. Our modern facilities stock a large range of sizes and grades, and we're ready to ship from stock right now.

From the first order on, you can depend on the J & L Stainless Steel Division in Detroit to give you quality, service and immediate shipment. Write or call for the latest complete stock lists.

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BERGENFIELD 8, NEW JERSEY

Stainless Steel . . .

and 302 steels deep drawn in the same dies. In most instances, however, the 202 samples were slightly harder and more magnetic than the 302 specimens. F. W. BOULGER

COLD WORKING OF METALS

One of the country's top scientists, M. Gensamer, coordinates the contributions of 17 experts. Discussed are strain hardening, deformation textures, recrystallization textures and more. 364 pages — 6x9 — red cloth — $5.00. *Clip and send to ASM Technical and Engineering Book Information Service, 7301 Euclid Ave., Cleveland 3, Ohio.*

Forging

Digest of "Opportunities I See For You", a talk by Harry W. McQuaid before the Drop Forging Assoc., Winter Industry Meeting, Dec. 10, 1957.

THE FORGING INDUSTRY operates primarily to furnish semifinished or rough parts for manufacturers of mechanical equipment such as the automobile and farm implement builders. It depends largely on the equipment designer not only for the design of the forging but also for the selection of the exact metal to be used in the forging.

The forging industry thus finds itself in the middle, between the steel industry and the manufacturing industry, and any important change in the forging industry must meet the approval of steel producers and fabricators. Conversely, any important change in steelmaking or in the customer's manufacturing practice will affect the forging industry. As an important customer of the steel industry, the forging industry must be alert to the present changes which are just around the corner in steel.

The high cost of new steelmaking equipment is causing the steel industry to check into methods for ore reduction in order to supply a charge material which will stabilize scrap costs and also provide a substitute for blast furnace hot metal. Both of these are apparently close to production and will go far to bring changes in the steel industry. The

STRAITS TIN REPORT

New developments in the production, marketing and uses of tin

MALAYAN TIN BUREAU

The new atomic power plant at Shippingport, Pa., has more than 58 miles of condenser tubes. They're made of an alloy containing from 0.9% to 1.2% tin.

★ ★ ★

Tests show that a new tin-cadmium alloy plating has greater corrosion resistance to salt spray, jet fuels, high temperature synthetic oils, and organic acid vapor than cadmium plating alone. It can be soldered the same way—and just as easily—as standard cadmium plated coatings.

★ ★ ★

Malaya has been the world's largest producer of tin for many years—over two-thirds of the tin consumed in this country is produced there. Straits Tin from Malaya is at least 99.87% pure and known throughout U.S. industry for its reliability and uniformity of grade.

★ ★ ★

A British firm recently developed a new solder paint for hot tinning or soldering stainless steel. The solder is simply painted on the steel and then heated to normal soldering temperature. Tin content ranges from 40% to 100% in the three grades manufactured.

Ask us to send you TIN NEWS, a monthly letter. It will keep you posted on tin supply, prices, new uses and applications.

The Malayan Tin Bureau
Dept. 25C, 1028 Connecticut Ave., Washington 6, D.C.

XXVII

This is the twenty-seventh of a series of advertisements dealing with basic facts about alloy steels. Though much of the information is elementary, we believe it will be of interest to many in this field, including men of broad experience who may find it useful to review fundamentals from time to time.

Cold-Finishing of Alloy Steels: The Effect of Cold-Drawing

The cold-drawing of alloy bars was discussed in the advertisement prior to this one, No. XXVI in the series. Here, we continue with a general explanation of the effect of cold-drawing.

During the cold-drawing process, certain changes take place in the steel structure, and in mechanical properties. There is a slight increase in tensile strength, compared with a substantial increase in yield point, and a decrease in ductility. These properties enable the production of small parts which require the greater strength necessary for certain automatic-machine forming operations, and a machine finish superior to hot-rolled material. Naturally, the beneficial effects of alloy steels are attained in the subsequent heat-treatment of parts.

The process of cold-drawing results in bars which are free from scale, accurate to shape, and within close tolerances. These conditions are ideal for automatic machining, as the elimination of scale is conducive to long tool life, and the accuracy of shape and close tolerances permit the bars to pass freely through the feed mechanism of the "automatic." Moreover, the cold-drawn finish and tolerances may be such that machining can be eliminated in some areas of the finished part. For example, sparkplug shells are produced from hexagon bars which require no machining on the hexagon sections.

Continuous roller hearths and car-bottom furnaces of both standard and controlled-atmosphere types, are used for special treatment of alloy bars before cold-drawing. Thermal stress-relieving can be used to reduce residual stresses in the steel caused by the cold-drawing process, wherein the mechanical properties will be altered depending upon the temperature used.

If you would like more specific details about the chemical composition or mechanical properties of cold-drawn alloy bars, and the results that can be expected, by all means consult our technical staff. Bethlehem metallurgists will gladly help you work out any problem, without cost or obligation on your part.

In the next advertisement, No. XXVIII in this series, the second category in cold-finishing will be discussed, i. e., the turning and grinding of alloy steel bars.

Remember that Bethlehem produces a wide and complete range of cold-drawn alloy steel bars in rounds, hexagons, squares, or flats, in standard, odd, decimal or metric sizes required, as well as special sections. Bethlehem also makes the full range of AISI standard alloy steels, and special-analysis steels and all carbon grades.

If you would like reprints of this series of advertisements from No. I to No. XXVII, please write to us, addressing your request to Publications Department, Bethlehem Steel Company, Bethlehem, Pa. The first 27 subjects in the series are now available in a handy 40-page booklet, and we shall be glad to send you a free copy.

BETHLEHEM STEEL COMPANY
BETHLEHEM, PA.

On the Pacific Coast Bethlehem products are sold by Bethlehem Pacific Coast Steel Corporation. *Export Distributor:* Bethlehem Steel Export Corporation

BETHLEHEM STEEL

Forging . . .

continuous casting of forging billets is also a possibility for the near future.

In the forging industry, the right answer is the production of more forgings from present equipment. This usually means finding more orders to reduce idle time to the minimum. This can be done if the over-all demand for forgings is increased to some extent.

In my opinion, the most stable business is the one which makes the more finished product. It would seem logical, therefore, for a forge shop to supply rough machined forgings or even finished machined heat treated forgings wherever possible. The sale problem might be simpler while the profit per piece would increase.

While many forgers are equipped with modern furnaces, many others still have inefficient furnaces. Forging furnaces have improved lately; there is more complete combustion of fuel oil, with higher flame temperature and much lower loss due to scaling. A furnace which represents the highest possible economy, highest furnace temperature and lowest scaling loss might be developed through coordinated research and development.

The typical forging can withstand a high degree of shock loading and will also deform greatly without fracture. Thus a forging is preferred to a casting when applied load is not known or shock loading is expected. The threat of the casting to the forging was not especially strong until the introduction of nodular cast iron, a high-grade cast iron with the free graphite in spheroidal form rather than flake. It can be described as a 0.90% C, high-silicon cast steel with excess graphite. The properties are comparable to those of a forging.

To the drop forger this is a possible loss of important tonnage to the foundry. The easy handling and machinability of the ductile iron castings may result in its approval for many applications. However, it will still be a casting and subject to the suspicion to which any iron casting is subject when considered for any important forging job. It would be logical for the industry to consider the forging of nodular iron which has been cast to a well-designed shape and would require few blows or pressings in a closed die to make the most accurate finished part possible. The air cooling of these forgings would produce a structure suitable for machining with properties which would be a definite improvement over those of any nodular iron casting. The first application for such a product will be where steel forgings are now used because of the increased factor of safety which a forging gives over a casting.

Another possible improvement is the establishment of a practice which will somehow make certain that when an order for an aircraft or bearing quality steel is taken the material specifications are followed. These give no unusual trouble with the large orders in the larger shops where proper technical inspection is available. In some of the smaller shops where the chemical specifications are about the only guide in applying steel which is available, a rejection by the customer because of magnetic, microscopic or other testing often makes a heavy loss inevitable. Just what actually constitutes "forging quality" in a forging billet is not too clear, and varies with the need for the steel in question and how badly the steel supplier thinks he needs the account it represents. The limitations imposed by such terms as "forging quality", "aircraft quality" and "bearing quality" should be well understood by the forger who is in the middle between the steel producer and the user of the forging.

Other subjects of interest to the forging industry are the handling of forgings of large cross section in heat treating, the advantages of caustic soda in quenching carbon and large-section low-alloy forgings, the effect of time in the quenching tank on internal stresses and quench cracking, and the control of flash line segregation and its effect on quench cracking. There is much which needs to be done in the technique and physical aspects of forgings as well as in the over-all economics of the product.

C. R. W.

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Handy & Harman Brazing Alloy Used in Diamond Tool Manufacture

This dramatic application of SIL-FOS clearly points out that, among this alloy's many qualities, its *versatility* is remarkable.

The A. I. T. Diamond Tool Company, Skokie, Illinois, uses SIL-FOS in powder form in the manufacture of its Al-Aloid diamond grinding wheel. The powdered SIL-FOS is mixed with the diamond dust and then sintered to form a wheel that in grinding "... holds sharp edges, does not heat or check carbides, lengthens life of carbide tools and does the work of four to six resin-bonded wheels."

SIL-FOS is one in a large family of Handy & Harman brazing alloys. It is a low-temperature alloy and is available in two analyses: SIL-FOS and SIL-FOS 5. These are silver-copper-phosphorus alloy systems; one contains 15% silver, the other 5%. Both have a wide melting range, starting to flow at 1185°F. and fully free flowing at 1300°F. Their "benefit categories" include: *joint strength, leaktightness, ductility, electrical conductivity, heat transfer, corrosion resistance, fast production and economy.* All of these qualities apply to joining a wide range of nonferrous metals, *as well as diamonds.*

There are many truly remarkable case histories of SIL-FOS brazing. We'd like very much to tell you about them and give you further details on what can be done for your product.

Your NO. 1 Source of Supply and Authority on Brazing Alloys

HANDY & HARMAN

General Offices: 82 Fulton St., New York 38, N. Y.

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Low-temperature silver alloy brazing with SIL-FOS *and* EASY FLO *is described in our Bulletin 20. Write for your copy.*

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4. Aircraft Fitting — Aluminum — 282 lbs. — 86 inches.
5. Aircraft Landing Gear — Aluminum 284 lbs. — 47 inches.
6. Missile Ring Splice — Aluminum — 54 lbs. — 20 inches.
7. Aircraft Spar Frame — Aluminum — 434 lbs. — 142 inches.
8. Missile Fin — Aluminum — 8 lbs. — 30 inches.
Faster and faster, higher and higher — greater stresses, increased temperatures — all leading to continually increasing dependence on forgings — and in the forging field there is no substitute for Wyman-Gordon quality, experience and know-how.

WYMAN-GORDON COMPANY

Established 1883

FORGINGS OF ALUMINUM • MAGNESIUM • STEEL • TITANIUM

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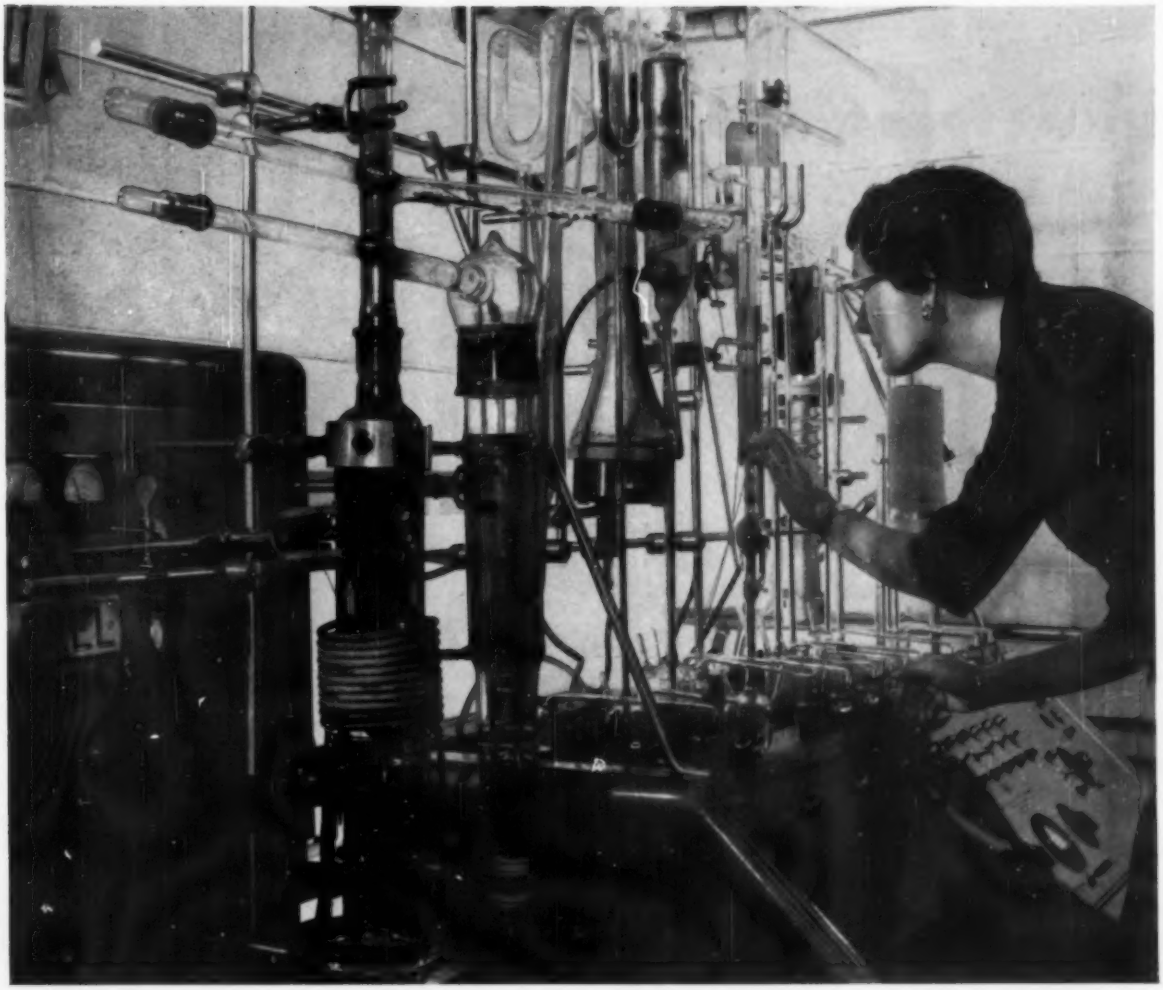

Know gas content in metals for improved product performance

Precise knowledge of gas content in metals, especially high temperature and reactive, can help you develop and maintain product superiority. To solve this analytical problem, you need good equipment and an intimate knowledge of how to secure the best results. Both the equipment and knowledge are available from NRC.

The precision, reliability, and convenience of NRC equipment reflect the experience gained through making over 15,000 analyses in our own laboratory plus the experiences and suggestions of our customers in over 140 installations throughout the world.

There are three basic models available to meet all requirements. When you buy from NRC our analysts install the equipment, train your operators, and thereafter are available for advice on new problems. If your volume is too small to justify the purchase of your own equipment, we can handle your work on a contract basis.

Contact us today to see how NRC analytical equipment or service can improve your product.

Oxygen, Hydrogen and Nitrogen content of most metals can be measured precisely in 40 to 70 minutes with the general purpose Model 912. Hydrogen alone in 4 to 8 minutes. Complete with installation and training $8,375.

Hydrogen in Titanium and Zirconium can be measured directly in 3 to 6 minutes. Precise measurement over concentration from 1 to 500 ppm. One aircraft engine maker reports 8,100 analyses in 7 months without trouble. Model 917 complete with installation and training $6,850.

Hydrogen in Steel which causes embrittlement and flaking can be determined quickly and precisely with the Model 916. Unit including installation and training, $8,000.

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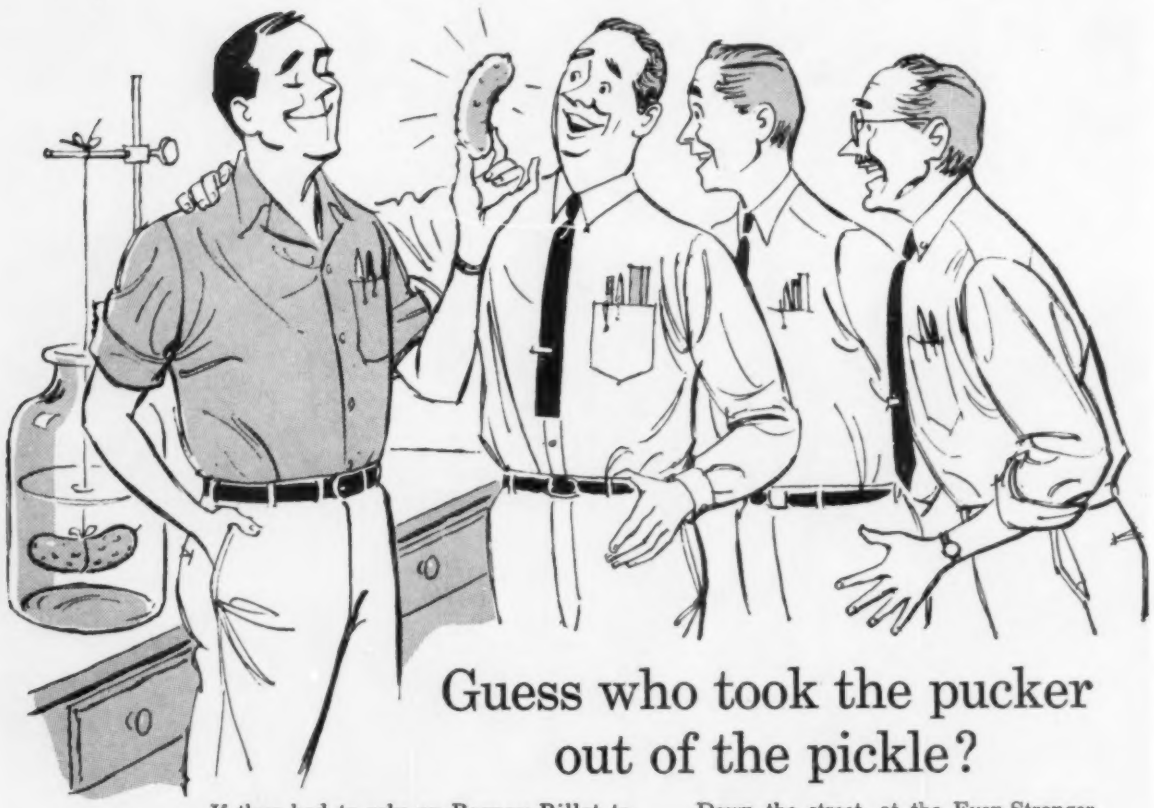
DEPT. 10, CHARLEMONT ST., NEWTON 61, MASS.

A Subsidiary of National Research Corporation

Any similarity to a real-life company is purely intentional



Guess who took the pucker out of the pickle?

If they had to rely on Barney Billet to keep the wolf from their doors, the pickle packers would soon pound a path to the poorhouse. For the truth is Barney doesn't like pickles. To him, a cucumber is just something to stay as cool as.

So what does Barney do for a living? Why he's a major-domo of a pickling tank at O-So-Strong Steel Company!

He does a good job — pushes plenty of tonnage through the tank. Barney rates ace-high with the top ingots (you wouldn't expect *brass* in a steel mill, would you?).

They've given him the finest equipment to work with. It's *got* to be good—the pickling operation uses a 12% sulphuric-acid solution at 200°F. And that can make a meal of most metals. But not of Ampco Metal! It's a series of special, super-tough copper-base alloys specially engineered to resist wear and corrosion.

That's why O-So-Strong fabricated the strip rollers and side plates from Ampco Metal. They're practically immersed in the pickling-tank solution—but meet the acid test without puckering.

Down the street, at the Even-Stronger Steel Company, replacement costs have dipped, also, since they've used Ampco Metal in pickling hooks, crates, baskets, yokes, and chains.

Ampco Metal has shown its mettle in other ways; for example, in rolling-mill applications where resistance to wear and shock loads is important — in screw-down nuts, screw-down worm wheels, slippers, breaker blocks, and other critical parts.

Though pickling may not have *you* in a pickle, chances are this story still applies to you. For nothing solves most wear, corrosion, erosion, abrasion, or cavitation problems like Ampco Metal. You can get it in any form — sand-cast, centrifugally-cast, shell-molded, precision-cast, forged, fabricated, extruded, sheet, or plate.

Your Ampco field engineer is the one to give you all the facts. Call him in. And write for Bulletin 33. *Ampco Metal, Inc., Dept. MP-3, Milwaukee 46, Wisconsin*

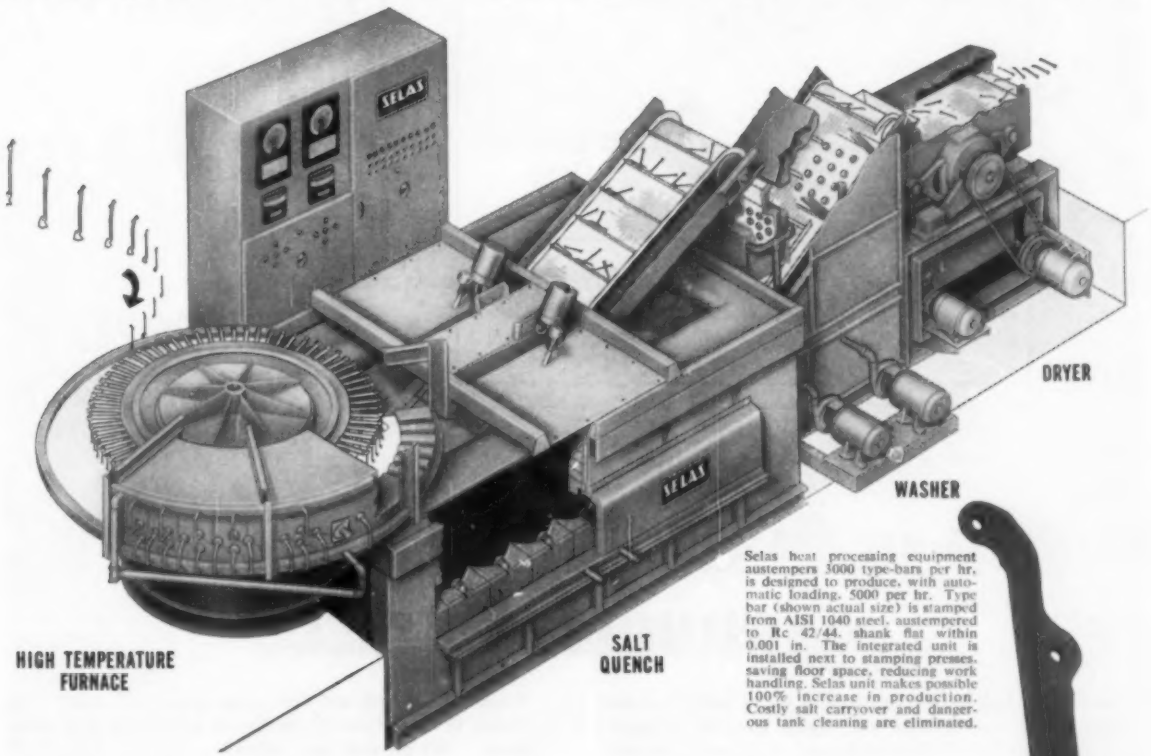
(West Coast Plant: Burbank, California)

AMPCO® METAL

The metal without an equal

our research is your reward

Selas custom-builds heat processing equipment to fit into your production line



Selas heat processing equipment austempers 3000 type-bars per hr, is designed to produce, with automatic loading, 5000 per hr. Type bar (shown actual size) is stamped from AISI 1040 steel, austempered to Rc 42/44, shank flat within 0.001 in. The integrated unit is installed next to stamping presses, saving floor space, reducing work handling. Selas unit makes possible 100% increase in production. Costly salt carryover and dangerous tank cleaning are eliminated.

Example: automatic austempering increases IBM type bar production 100%

For more than a year, this Selas custom-built heat-treating equipment has been turning out a better product, saving valuable floor space, reducing materials handling.

Based on satisfactory experience with this equipment, a second similar Selas unit, austempering another electric typewriter component, is scheduled to go into production at IBM this month.

Time-saving, space-saving, materials-saving heat processing equipment is designed and built by Selas to meet your specific needs. If desired, the complete Selas unit may be shipped intact to your plant, ready for insertion into your production line . . . ready, too, to perform its designated heat processing functions immediately upon hook-up to power.

For any type of heat processing, for small or large parts, Selas can design and build automatic or semi-automatic equipment to fit into your production line. To learn how Selas can help you solve your heat processing problems, write Department 33, Selas Corporation of America, Dresher, Pa.

SELAS
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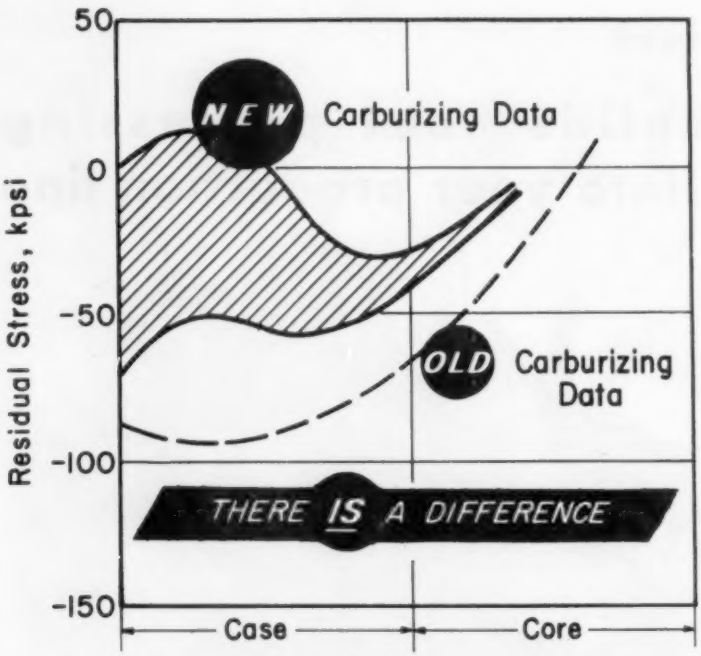
Heat and Fluid Processing Engineers
DEVELOPMENT • DESIGN • CONSTRUCTION



residual stress distribution in a typical application

fatigue durability of carburized steel

AN IMPORTANT NEW ASM BOOK

WRITTEN FOR MEN WHO SPECIFY, DESIGN, PRODUCE or USE

CARBURIZED STEEL

This book can help you as you work with carburized steel. Here, for men who specify, design, produce, or use carburized steel, is a valuable aid in determining effective applications. Here, for you, are current, authoritative findings you can use for the better performance of your work.

Don't overlook this opportunity to be up-to-date.

From the graph on this page you will note that there IS a difference between *old* data and *new* data. Which are you using?

Fatigue Durability of Carburized Steel is the work of seven authorities of the General Motors' Corporation Research Staff. Take advantage of their work to update yours.

INCLUDING

Introduction
By J. B. Bidwell, Head, Engineering Mechanics Dept., Research Staff, General Motors Corporation

Effect of Surface Condition on the Fatigue Resistance of Hardened Steel
By G. H. Robinson, Supervisor, Ferrous Metallurgy, Research Staff, General Motors Corporation

Residual Stresses in Carburized Steels
By J. G. Roberts, Research Engineer, and R. L. Mattson, Assistant Head, Engineering Mechanics Dept., Research Staff, General Motors Corporation

Summary
By R. F. Thomson, Head, Metallurgical Engineering Dept., Research Staff, General Motors Corporation

(Published 1957) A series of educational reports on fatigue durability of carburized steel. By seven authorities. 123 pages. 6¼ x 9¼. Red cloth binding. 94 graphs, tables and photographs. 45 literature references. American Society for Metals.

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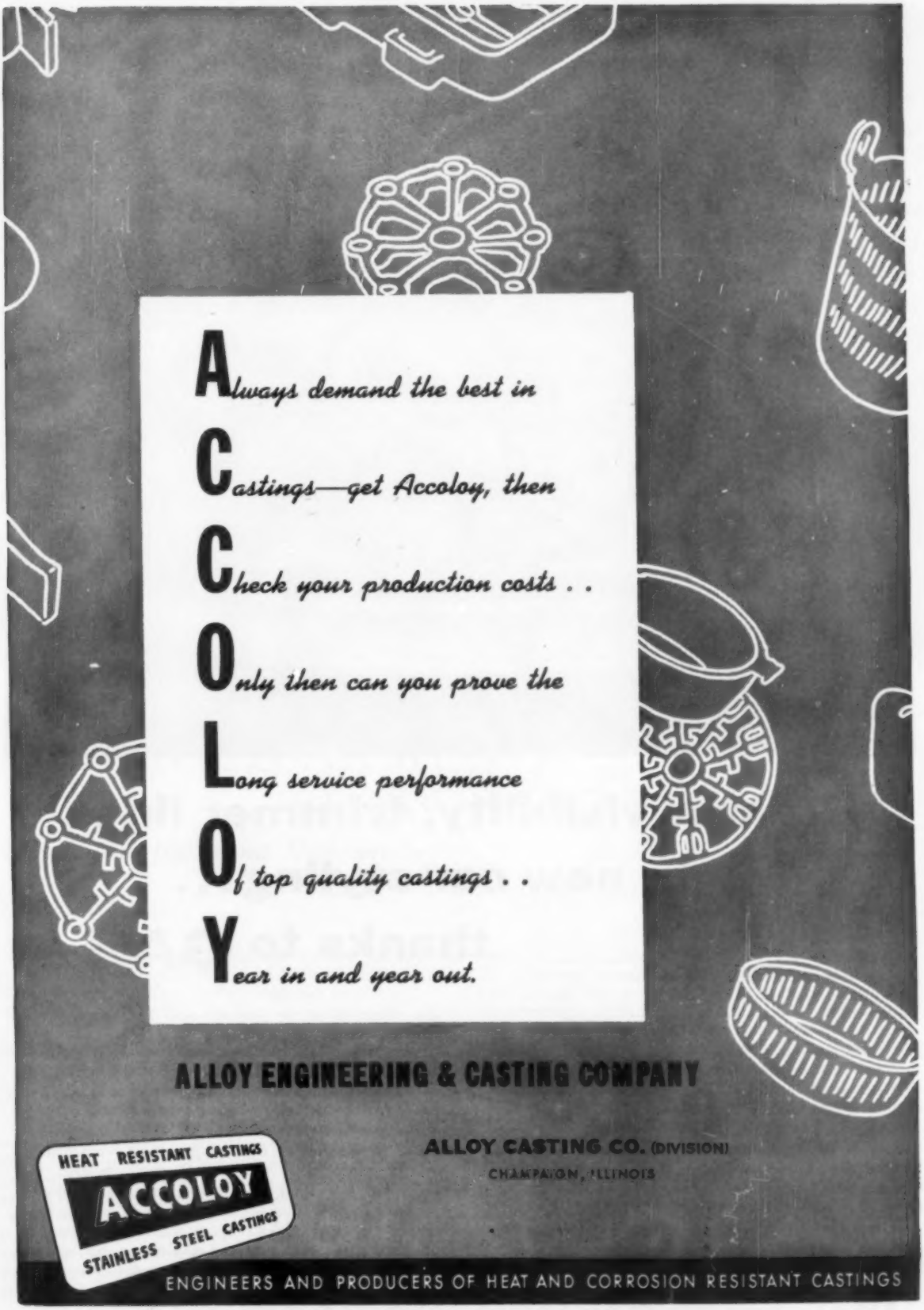
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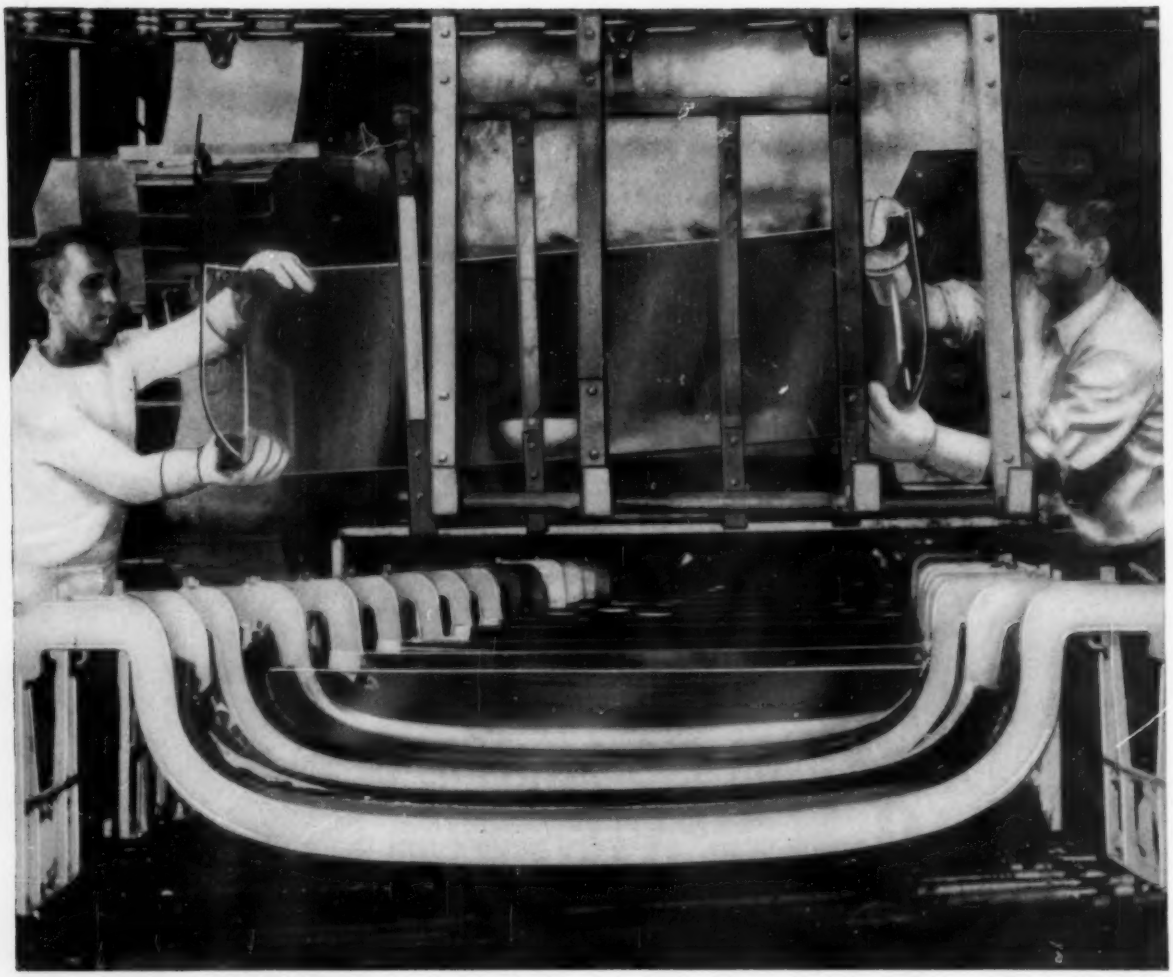

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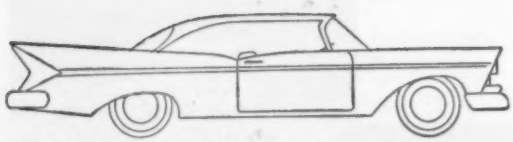

With nearly 7,000,000 cars being produced annually, the increased use of glass has demanded major production improvements in the manufacture of new panoramic windshields and back-lights.

Since the forming of the intricately curved glass is done at a temperature at which glass is soft and can be bent, the production process challenged heat process engineers to design new automatic equipment capable of mass producing these large precision glass pieces.

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The story of Wissco Belts is best told by their users. For instance, Mr. Henry Colenso, Plant Engineer of the Long Manufacturing Division, Detroit, Michigan says:

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"Since our Wissco Belt was installed about six months ago, we have not had one single belt breakdown. The main reason for its continued successful operation is its thin, flat spiral construction," Mr. Colenso continues. "The spirals in the belt are preseated during manufacture, and the belt has not stretched during operation. Compared with other belts we have used, and we've made many experiments, the Wissco Belt has proven outstanding for long life and continuous service."

What Wissco Belts have done for Long Manufacturing, they can do for you in your processing-conveying operations. For further information contact the sales office nearest you.

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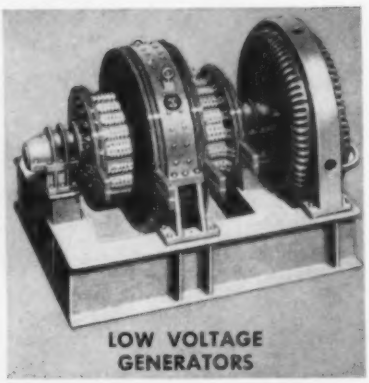

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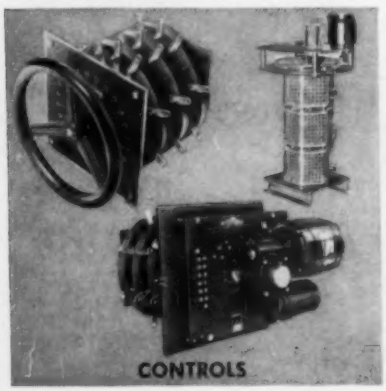

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ZINC DIE CASTINGS REPLACE ALUMINUM

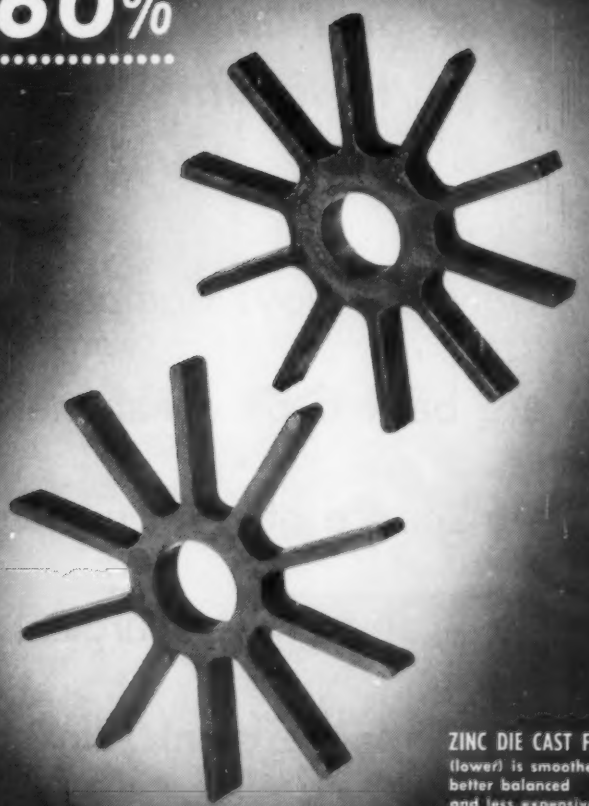
in Redesigned Motor Fan

REDUCES COST OVER 60%

Conversion to zinc die castings from aluminum sand castings enabled Baldor Electric Co., St. Louis, Mo. to reduce material and labor costs on its fans by as much as 61%, and speed up production as well. The fan is used to cool the manufacturer's line of induction motors.

The aluminum sand castings previously used were often irregular and unbalanced, and required expensive finishing and machining operations.

The fans, die cast in zinc by A. B. Mueller Co. of St. Louis, Mo., requires no protective finishing because of the inherent corrosion resistance of zinc, and most secondary operations have been eliminated. The shaft hole diameter of the fan is held within ± 0.005 in. as cast — additional proof that of all the metals commonly used in die casting, zinc alloys rate highest in dimensional accuracy.



ZINC DIE CAST FAN (lower) is smoother, better balanced and less expensive to produce than aluminum sand cast fan.

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● Oakman Manufacturing Company, large Detroit stamping firm, found it difficult to deep draw steel bumper guards. Complex bends, up to 120 degrees, produced extra stress and strain on the $1800 chrome-plated drawing die.

It was necessary to stone the die surface every hour, and hand polish entire drawing surface after each day's run. The steel die had to be completely reworked and a new chrome-plated surface added after drawing 60,000 parts. Downtime for maintenance made it difficult to maintain production schedules. Maintenance costs soared.

A Grade C-80 Talide die ($2700) was installed 8 months ago. To date it has drawn over 800,000 guards with no wear in evidence. Downtime for die maintenance has been greatly reduced. A buffing operation (25c per piece), previously required, has been entirely eliminated because of the smoother, brighter, more durable finish achieved with the Talide die.

A Talide die engineer can help you cut costs and increase production on draw presses, punch presses, pill presses, cold headers, swagers and draw benches. **METAL CARBIDES CORPORATION, 6001 SOUTHERN BLVD., YOUNGSTOWN 12, OHIO.**

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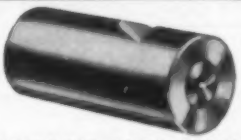

HEADING AND EXTRUSION DIES

Cold heading ¼" C-1008 rivets, TALIDE dies produced 11,200,000 pieces, other carbide dies only 3,500,000.

CURLING ROLLERS

TALIDE Curling Rolls last 65 times longer than steel rolls on beverage can forming operation.

BLANKING AND FORMING DIES

70 times more paper discs blanked out with TALIDE—over hard alloy die.

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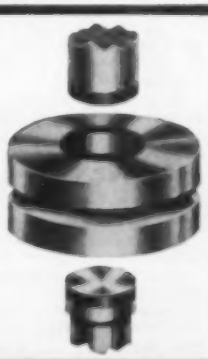
Compacting highly abrasive chemical powders, TALIDE pill dies last 4 months, steel dies wore out in 6 hours.



OTHER IMPORTANT ASM METALS BOOKS YOU SHOULD HAVE FOR HANDY REFERENCE

ALLOY CONSTRUCTIONAL STEELS

By H. F. French, International Nickel Co., with a joint paper by F. L. LaQue on Corrosion

Here is a book which was prepared as a word-picture of the activities of alloys in constructional steel. It is also intended to provide data which might help the reader in the selection of steels for different classes of service. In a large sense, the material has been assembled with the view of illustrating alloy steels in our current industrial civilization. There are five sections in the book with numerous illustrations, graphs, and charts. It is well indexed both from a standpoint of subject matter and author references. A truly valuable reference work for all metal engineers. 1942.

300 pages.....6 x 9.....red cloth.....$4.50

EFFECT OF RESIDUAL ELEMENTS ON THE PROPERTIES OF METALS

The effect of residual elements on the properties of metals is the central theme of this volume, originally presented as an ASM educational lecture at the 1956 National Metal Congress in Cleveland. E. R. Parker, University of California discusses fundamental considerations —such as structure—formation of second phase effects of soluble elements and second phases upon properties. F. N. Rhines, Carnegie Tech, presents a paper on the impurities in the common nonferrous metals—such as aluminum, magnesium, copper and nickel. The residual elements in steel is discussed by J. W. Halley, Inland Steel Company. W. G. Pfann, Bell Telephone Laboratories, presented a discussion on impurities in semiconductors, a lecture originally prepared by J. H. Scaff, also of Bell Telephone Laboratories. The newer metals—titanium, zirconium, molybdenum and chromium are metals covered in a discussion by D. J. McPherson, Armour Research Foundation. 1957.

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BEHAVIOR OF METALS UNDER IMPULSIVE LOADS

By John S. Rinehard, Research Physicist, and John Person, Research Engineer, Michelson Laboratory, U. S. Naval Ordnance Test Station, China Lake, California

Concept of Impulsive Loading—Properties of Materials Under Conditions Imposed by Impulsive Loading—Propagation of Transient Disturbance—Explosives and Explosions—Characteristics of Impulsive Loads—Methods of Observation and Apparatus: Nonphotographic—High Speed Photographic Techniques—Inelastic Behavior Under Nonimpulsive Loading—Fracturing Under Impulsive Loading—Plastic Deformation Under Impulsive Loading—Structural Changes Under Impulsive Loading—Behavior Under Impact—Practical Application of Explosives. 1954.

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FATIGUE

A series of educational lectures on Fatigue presented to members of the ASM during the 35th National Metal Congress in Cleveland, October 19-23, 1953

Basic Concepts of Fatigue Damage in Metals—By T. J. Dolan, Professor and Head, Department of Theoretical and Applied Mechanics, University of Illinois, Urbana, Ill.

Fatigue Failure Under Resonant Vibration Conditions—By B. J. Lazan, Professor and Head, Department of Mechanics and Materials, University of Minneapolis, Minn.

Fatigue Characteristics of Large Sections—By O. J. Horger, Chief Engineer, Railway Division, Timken Roller Bearing Co., Canton, Ohio. 1954.

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CREEP AND RECOVERY

This book contains the papers presented at the Annual ASM Seminar in Cleveland in 1956. As with previous ASM Seminars this book is of an exceptionally high character.

Dr. R. Maddin was coordinator of the two-day Seminar sessions.

The Concept of Creep—Defects and Recovery—The Thermodynamics and Kinetics of Recovery—Polygonization—Recovery of Electrical Resistivity—Recovery of Mechanical Properties—Recovery of Internal Friction and Elastic Constants—Theory of Creep—The Role of the Boundary in Creep Phenomena—The Effect of Alloying Elements on Creep—The Spectrum of Activation Energies for Creep—Creep and Fracture—Creep of Crystalline Non-Metals. 1957.

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ENGINEERING ALLOYS

By N. E. Woldman, Consulting Engineer

Over 19,000 alloys are listed in this one-volume library of alloy information. This book lists alloys by trade name and by manufacturer. It gives properties, compositions, and typical applications.

Engineering Alloys is a revision and an extension of the former volume published by the American Society for Metals.

The new edition is divided into five sections: (1) An alphabetical listing of all commercial alloys. (2) Alloy data, including names, properties and uses. (3) A directory of manufacturers and their alloys. (4) A key index and discussion of manufacturers. (5) An appendix classification of corrosion and heat resistant alloys with definitions and heat-treating terms.

Included in the new volume will be testing and other useful tables.

All important commercial alloys from all over the world are shown in this alloy encyclopedia as the result of ten years of painstaking effort on the part of the author and the alloy manufacturers. Revised 1954.

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MOLY NEWS

CLIMAX MOLYBDENUM, 500 FIFTH AVENUE, NEW YORK 36, N. Y.

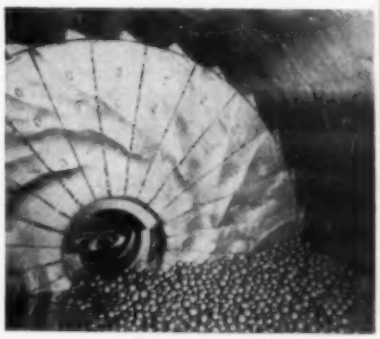
Chrome-Moly Steels Prove Ability To Resist Wear and Abrasion, Cut Costs

Can be Adapted to a Wide Range of Uses

To offset rising equipment and maintenance costs, the savings possible with wear-resistant alloy steels are receiving increasingly wide attention, in a growing number of industries.

Two types of "Chrome-Moly" steels show exceptional resistance to abrasion and wear under toughest conditions. Both have substantially cut liner costs and shutdown time in grinding mills. Both are suitable for a variety of other industrial applications because they combine wear resistance, favorable first cost, freedom from premature failure by breakage or spalling, resistance to flow in service, consistently uniform performance and adaptability to specific designs.

The two types are Pearlitic (250-450 BHN) and Martensitic (450-700 BHN). Carbon and alloy contents and heat treatments of both types can be varied to suit specific applications.



Note that the spiral wear pattern is clockwise, even though the mill's rotation is counter-clockwise. Type 2 Martensitic steel is used here.

For an article on the use of Chrome-Moly steels, send for "How to Select Chrome-Moly Steels for Ball and Rod Mill Liners" by T. E. Norman, reprinted from Engineering and Mining Journal. Circle #1 on the coupon.

New Use For Super-Strength Structural Steels

Today, gasoline trailer tanks are built of super-strength structural steels for a good reason. The steels have high strength/weight ratios. This factor enables builders to design tanks that carry greater payloads and still meet legal gross weight limits. And the extra capacity pays for the higher trailer cost in a few months!

This use is only one of countless possibilities for utilizing the steels' minimum yield strengths of 55,000 to 150,000 psi . . . and their many other desirable properties. *For more information, including tradenames and compositions, ask for "Super-Strength Structural Steels." Circle #2.*

Sums Up Moly's Resistance to Corrosion

A new paper, "Corrosion Resistance of Molybdenum and Molybdenum-Base Alloys," based on published literature, summarizes moly's resistance to a number of corrosive media. It also lists the reference articles. For a copy of this paper, *circle #6.*

Molybdenum Improves Corrosion Resistance of Stainless Steels

Translated excerpts from two French articles discussing how moly improves the corrosion resistance of austenitic and austenitic-ferritic stainless steels are now available. *Circle #7.*

Special Steels Solve Hydrogen Sulphide Problem

Hydrogen sulphide in France's Lacq natural gas field brought up a metallurgical problem: the need for tubing meeting the N-80 strength requirements but with better resistance to sulphide stress corrosion than the conventional N-80 grade. Two such steels have been developed. One contains chromium, aluminum and molybdenum; the other contains chromium, molybdenum and vanadium.

For articles discussing both steels, send for "A Special N-80 Steel Tubing . . . " by Cauchois, Didier and Herzog, reprinted from *Corrosion*, and "Comments on new French N-80 Steels" published by Climax. *Circle #3.*

Vanadium in Low-Alloy, High-Temperature Steels

Molybdenum is a must in low-alloy, high-temperature steels. However, recent tests at the U.S. Naval Research Laboratory point up the role of Vanadium in such steels, and show the effect of variations in composition and treatment. Addition of Vanadium results in a better high-temperature alloy, but getting the improvement requires higher normalizing temperatures.

The advantages and limitations are described in an *Iron Age article*, "Higher Vanadium Improves Hot Strength of Low Alloy Steel," by Paul Shahinian and J. R. Lane. *For reprints, circle #4.*

New Cleaner Removes Surface Oxides From Moly Metal

A practical, low-temperature method of cleaning molybdenum has recently been developed. It is especially suitable for removing surface oxides prior to welding. The process involves two chemical baths: one at 150-180°F, the other at room temperature. *Digested from "Ryan Devises Molybdenum Cleaner," Ryan Aeronautical Company. For reprints, circle #5.*

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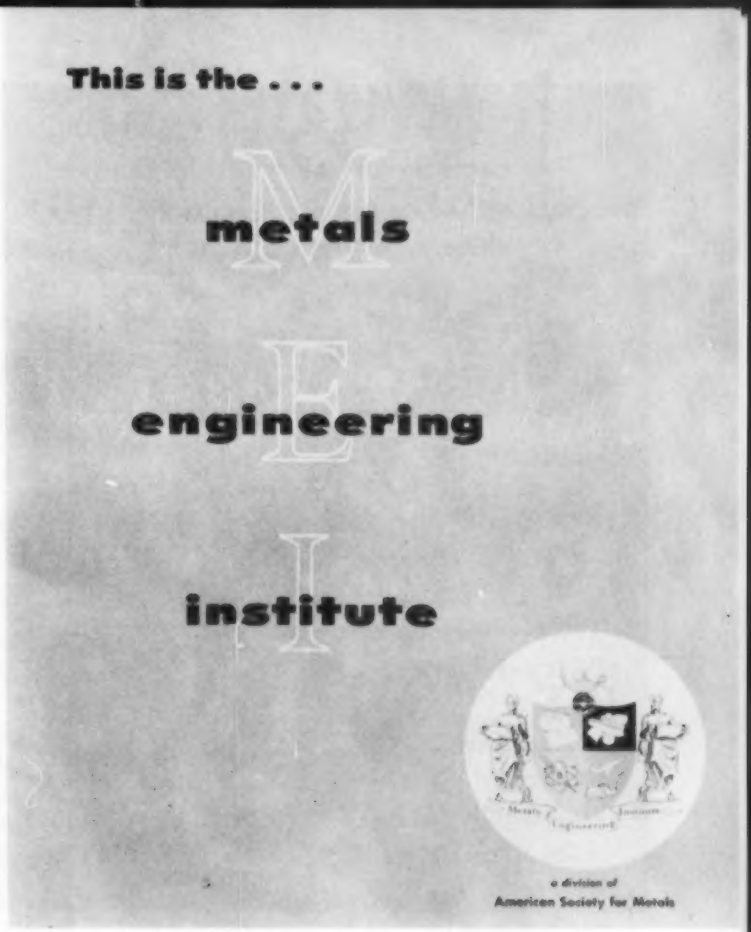

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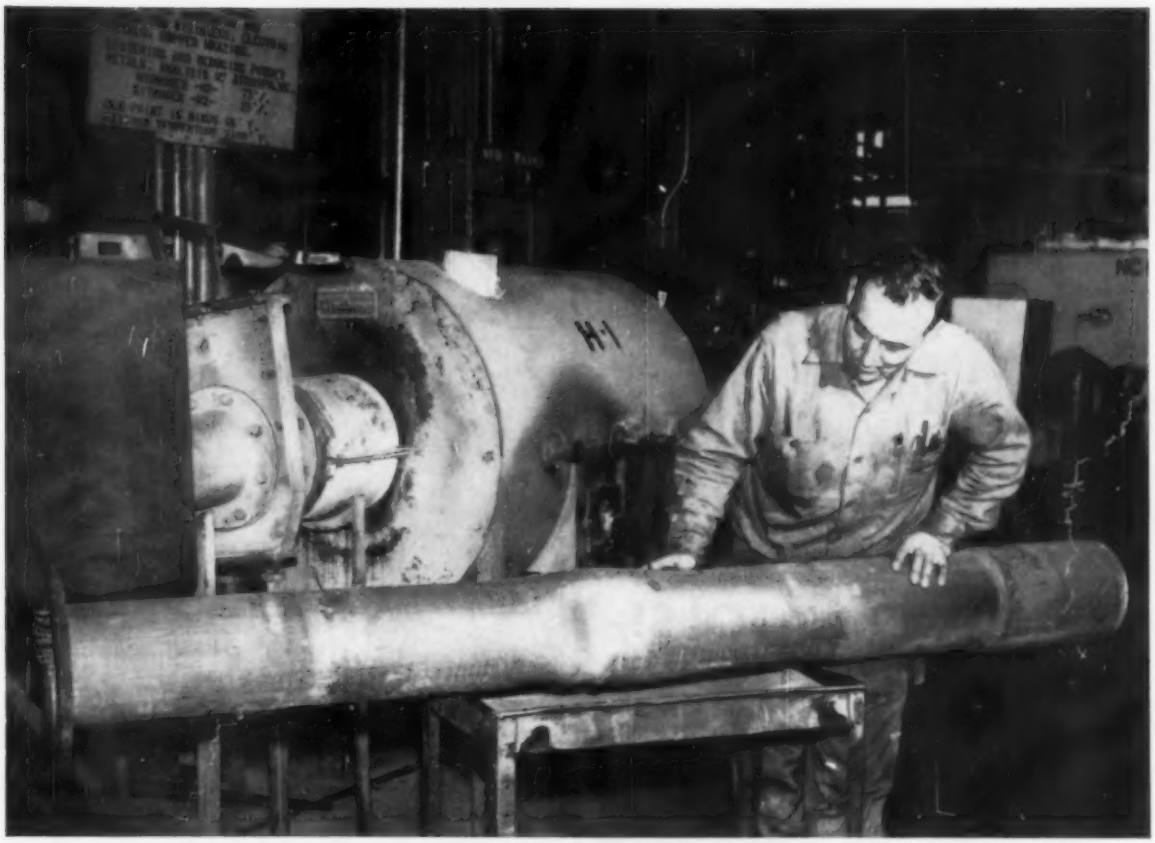

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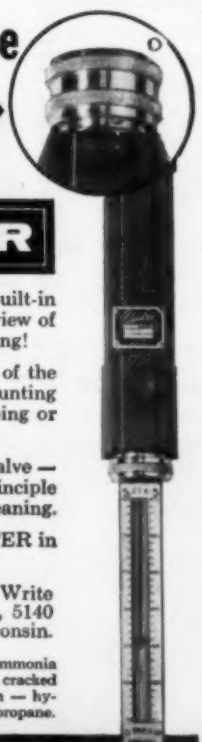

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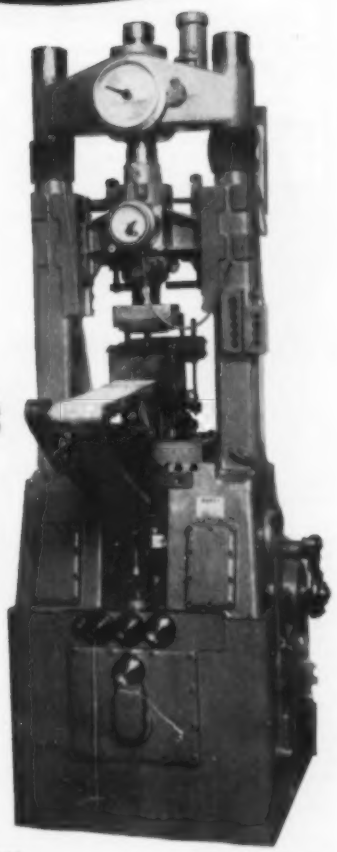

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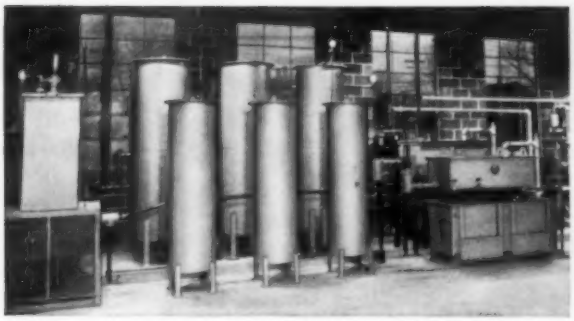

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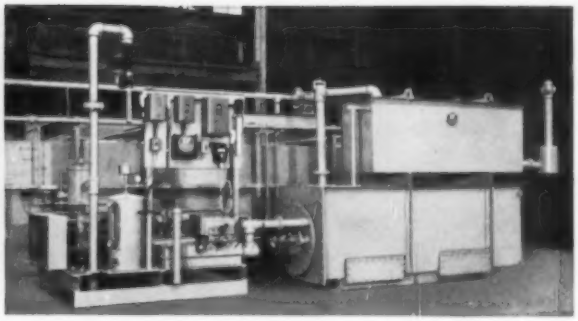

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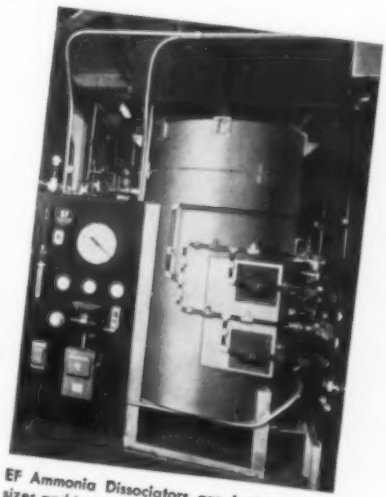

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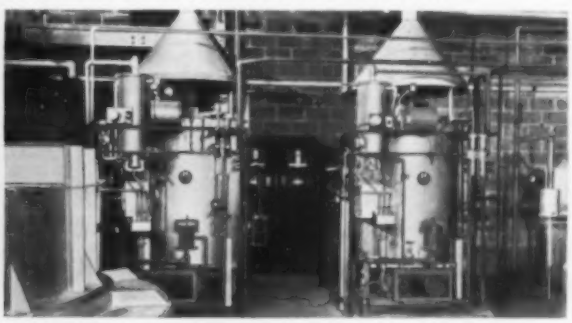

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